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LOADS AND AEROELASTICITY DIVISION RESEARCH AND TECHNOLOGY ACCOMPLISHMENTS FOR FY 1983 AND PLANS FOR FY 1984

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LOADS AND AEROELASTICITY DIVISION
RESEARCH AND TECHNOLOGY ACCOMPLISHMENTS FOR FY 1983
AND PLANS FOR FY 1984

SUMMARY

The purpose of this paper is to present the Loads and Aeroelasticity Division's research accomplishments for FY 83 and research plans for FY 84.The work under each branch (technical area) will be described in terms of highlights of accomplishments during the past year and highlights of plans for the current year as they relate to five year plans and the objectives for each technical area. This information will be useful in program coordination with other government organizations and industry in areas of mutual interest.

ORGANIZATION

The Langley Research Center is organized by directorates as shown on figure 1. The top three perform support functions and the bottom four conduct the research program. A directorate is organized into divisions as illustrated on the figure for the Structures Directorate.

The Loads and Aeroelasticity Division (LAD) consists of four branches as shown on figure 2. This figure lists the key people in the division which consists of 72 NASA civil servants and six members of the Army Structures Laboratory (of the Army Aviation Research and Development Command) located at the Langley Research Center. Each branch represents a technical area and disciplines under the technical areas are shown on the figure. All of the Army personnel work on the disciplines Rotorcraft Aeroelasticity and Rotorcraft Vibrations.

The division conducts analytical and experimental research in the four technical areas to meet technology requirements for advanced aerospace vehicles. The research focuses on the long range thrusts shown in figure 3 with the LAD having lead responsibility in the first three. The Unsteady Aerodynamics Branch (UAB), Configuration Aeroelasticity Branch (CAB), and Multidisciplinary Analysis and Optimization Branch (MAOB) all work in the area of Control of Aeroelastic Stability and Response. The MAOB also works the area of Computerized Analysis and Synthesis. The Aerothermal Loads Branch (ALB) works the area of TPS for Advanced STS and performs most of the research in the last three thrusts which the LAD supports.

RESEARCH PHILOSOPHY

The basic philosophy and motivation of the Loads and Aeroelasticity Division research program can be captured in some quotes from the giants on whose shoulders current researchers now stand. In his 13th Von Karman lecture on Aeroelasticity (ref. 1), I. E. Garrick related the following: "Von Karman's sense of humor, which was remarkably appropriate to a given occasion, has become legendary. Recognizing that the poor structures engineer was usually held accountable for structural integrity, he quipped, 'The aerodynamicist assumes everything but the responsibility.'"

"It has been gratifying to me to observe that in major aerospace industry the aeroelastician is no longer the stepchild he once was. From an almost parochial isolated specialist, he is now the generalist who tends to pull together the separate efforts in structures, aerodynamics, stability and control, and propulsion, even in early design stages. Yet, there are still human problems such as one-way communications and barriers between departments as well as physical problems that are often so recondite and difficult that aeroelastic problems may slip through the cracks."

In his Wright Brothers Lectureship in Aeronautics on Optimization (ref. 2), Holt Ashley observed: "Further mention will be made in what follows of the keen disappointment felt by many specialists because their theories have received so little practical application. This phenomenon is frequently attributed to a reluctance by developmental engineers to adopt unfamiliar and untried methods of analysis. Accepting this as a partial explanation, one can further speculate that the difficulty of efficiently formalizing a realistic design or operational question may be another source of discouragement. Today it requires much more knowledge and understanding on the user's part to exercise successfully a package of optimization software than, by comparison, to stress-analyze a complicated structure by means of a finite-element code."

The Loads and Aeroelasticity Division program is aimed at producing the data and analysis methods required by those who are accountable for the structural integrity of aerospace vehicles, to continue to pull together those separate efforts that ought to (or must) be considered as a single task, to preclude aeroelastic problems from slipping through the cracks, to alleviate the reluctance by developmental engineers to adopt unfamiliar and untried methods by making them both familiar and proven, and finally, to enhance the understanding of optimization methods so they will "fear not to touch the best" (ref. 2).

FACILITIES

The Loads and Aeroelasticity Division has two major facilities available to support its research as shown in figure 4.

The Transonic Dynamics Tunnel (TDT) is a Mach 0.2 to 1.2 continuous flow variable pressure wind tunnel with a 16 ft. square test section which uses a freon-12 test medium primarily for dynamic aeroelastic testing. The tunnel operates at dynamic pressures up to 2.5 psi and Reynolds numbers up to 8×10^6/ft. This unique facility is used primarily by the Configuration Aeroelasticity Branch using side-wall mounted models and cable-mounted models of conventional type aircraft. On occasions, the ARES (Aeroelastic Rotor Experimental System) test stand is used in the tunnel to study the aeroelastic effects on rotors. A Hover Facility, located in B-647, is used to setup the ARES test stand in preparation for entry into the TDT. A modernization of the TDT Data Acquisition System is underway along with a major CofF activity for density increase. Replacement cost for this facility is $63M.

The Aerothermal Loads Complex consists of six facilities which are used solely by the Aerothermal Loads Branch to carry out their research. The 8-Foot High Temperature Tunnel (8' HTT) is a unique hypersonic Mach 7 blowdown wind tunnel with an 8' diameter test section (usable test core of 4') that

uses products of combustion (methane and air under pressure) as the test medium. The tunnel operates at dynamic pressures of 2 to 12 psi, temperatures of 2000 to 3000°F and Reynolds numbers of 0.3 to 3.0 x 10^6/ft. The tunnel is used to test flat and curved surface type models to determine aerothermal effects and to evaluate new concepts for Thermal Protection Systems (TPS). A major CofF item is being proposed to provide alternate Mach number capability and to provide O_2 enrichment for the test medium. This is being done primarily to allow the tunnel to test models that have hypersonic air breathing propulsion applications. Replacement cost for the tunnel is $44M.

The 7-Inch High Temperature Tunnel (7" HTT) is a 1/12 scale of the 8' HTT with basically the same capabilities as the larger tunnel. It is used primarily for blockage studies for models being placed in the 8' and also it is used to aid in the design of larger models. The cost of models is greatly reduced by trying out scaled models in the small tunnel. The 8' could damage very expensive models if certain system checks and tunnel operating conditions had not been defined first using this facility. The 7" HTT is currently being worked to upgrade its control system and to also provide O_2 enrichment so its capability can stay current with the 8' HTT. This will also aid in the development of the 8' HTT O_2 enrichment system. Replacement cost for the tunnel is $1.0M.

The 1 x 3 High Enthalpy Aerothermal Tunnel (1 x 3 HEAT) is a unique facility designed to provide realistic environments and times for testing thermal protection systems proposed for use on high-speed vehicles such as the Space Shuttle. The facility is a hypersonic blowdown wind tunnel that uses products of combustion as the test medium. Test panels mounted on the sidewalls can be as large as 2' high x 3' long. The facility operates at dynamic pressures of 1 to 10 psi, Mach numbers from 4.7 to 3.5 depending on the temperatures, temperatures from ambient to 5800°F, an altitude range simulating flight of 130,000 to 80,000 ft., and Enthalpy levels from 1100 to 4400 BTU/lb depending on the oxygen levels used in the test medium. Replacement cost for the tunnel is $8M.

The three Aerothermal Arc Tunnels (20 MW, 5 MW and 1 MW) are used to test models in an environment that simulates the flight reentry envelope for high speed vehicles such as the Space Shuttle. The amount of usable energy to the test medium in these facilities is 9 MW, 2 MW, and 1/2 MW. The 5 MW is a three phase AC arc heater while the 20 MW and 1 MW are DC arc heaters. Test conditions such as temperature, flow rate, and enthalpy vary greatly since a variety of nozzles and throats are available and since model sizes are different (3" diameter to 1' x 2' panels). The AAT has a CofF activity proposed to increase the steam supply line capacity. Replacement cost for these arc tunnels are $23M.

FY 83 ACCOMPLISHMENTS

Aerothermal Loads Branch

The Aerothermal Loads Branch conducts research (figure 5) to develop and validate solution algorithms, modeling techniques, and integrated finite elements for flow-thermal-structural analysis and design; to identify and understand flow phenomena and flow/surface interaction parameters required to

define detailed aerothermal loads for structural design via analysis and test; and to verify practical and durable thermal protection system concepts for space transportation systems via analysis, laboratory, and wind tunnel tests. This work is more clearly identified in figure 6 which shows the five year plan of the four disciplines and their expected results.

The Aerothermal Loads FY 83 accomplishments listed below are highlighted by figures 7 through 16.

TPS Concepts:
- Non-Catalytic Coating for Metallic TPS Reduces Heating
- Preliminary Evaluation of Bonded MW/RSI Tile is Successful
- LaRC Tests Certify Thermal Barrier and Pressure Seal
- Aerothermal Tests of Metallic TPS

Thermal Loads:
- Tests in the 8' High Temperature Tunnel Show Mass Addition Film Cooling Alters The Shock Layer Flowfield in Addition to Surface Pressure and Heating
- Aerodynamic Heating and Pressure Distributions on a blunted Three-Dimensional Nonaxisymmetric Body at Mach 6.8

Integrated Analysis:
- Unified Thermal/Structural Analysis
- Aerothermal Loads Analysis of High Speed Flow Over Quilted Surface Configurations

Facilities Operations and Development:
- Remote Multiplexed Data System with Fiber Optic Link Proven in LaRC 8-Foot High Temperature Tunnel
- Oxygen Enrichment and Alternate Mach Number Study of the 7" HTT Pilot Model for the 8' High Temperature Tunnel

Each highlight is accompanied by descriptive material.

Multidisciplinary Analysis and Optimization Branch

The Multidisciplinary Analysis and Optimization Branch conducts research (figure 17) to develop a methodology for optimization of aircraft and spacecraft for best performance, and to develop the technology to reduce loads and increase the dynamic structural stability of flexible airframes by the use of active controls; to obtain transonic loads data and validate methods for aeroelastic design, including active control concepts, through wind tunnel and flight tests utilizing drone aircraft; and to develop and validate thermal-structural analysis and design methods tailored for repetitive application in optimization under a variety of constraints and loads. This work is more clearly identified in figure 18 which shows the five year plan of the four disciplines and their expected results.

The Multidisciplinary Analysis and Optimization FY 83 accomplishments listed below are highlighted by figures 19 through 27.

Active Controls:
- GLA Analysis Methods Validation
- Multiloop System Gain and Phase Margin Optimization
- Comparison of Experimental Control Surface Unsteady Aerodynamics With Doublet Lattice Predictions

Design Oriented Analysis:
- Analytical Technique Demonstrates Control of Space Structure Thermal Distortion by Applied Heating
- Application of Reduced Basis Method to Transient Thermal Analysis

Flight Loads:
- SPAN-MAT: Spanwise Measurement of Atmospheric Turbulence
- DAST ARW-2 "Hardware in the Loop" Simulation Testing

Optimization and Applications:
- Structural Optimization Executed on CRAY-1 Ten Times Faster Than on CYBER-173
- New Ground Broken in Structural Dynamics Optimization

Each highlight is accompanied by descriptive material.

Unsteady Aerodynamics Branch

The Unsteady Aerodynamics Branch conducts research (figure 28) to produce, apply, and validate through experiments a set of analytical methods for predicting steady and unsteady aerodynamic loads and aeroelastic characteristics of flight vehicles--with emphasis on the transonic range. This work is more clearly identified in figure 29 which shows the five year plan of the three disciplines and their expected results.

The Unsteady Aerodynamic FY 83 accomplishments listed below are highlighted by figures 30 through 36.

Theory Development:
- New Differencing Scheme for Transonic Calculations Eliminates Entropy-Violating Expansion Shocks
- Improved Modeling Increases Accuracy of Unsteady Transonic Calculations
- Unsteady Surface Pressures on Clipped Delta Wing Obtained From Panel Method and Experiment
- Velocity Potential Smoothing Technique Accelerates Convergence of Transonic Calculations
- Lifting Surface Theory Applied to a Helicopter Rotor in Forward Flight

Aeroelastic Analysis:
- Assessment of 2-D Airfoil Transonic Flutter Characteristics

Unsteady Pressure Measurements:
- DAST ARW-2 Shows Unusual Transonic Instability Boundary

Each highlight is accompanied by descriptive material.

Configuration Aeroelasticity Branch

The Configuration Aeroelasticity Branch conducts research (figure 37) to produce, apply, and validate through experiments a set of analytical methods for predicting steady and unsteady aerodynamic loads and aeroelastic characteristics of rotorcraft; to determine, analytically and experimentally, effective means for predicting and reducing helicopter vibrations and to evaluate the aeroelastic characteristics of new rotor systems; to develop the aeroelastic understanding and prediction capabilities needed to apply new aerodynamic and structural concepts to future flight vehicles and to determine and solve the aeroelastic problems of current designs; and to flight test a pylon which will suppress wing/store flutter. This work is more clearly identified in figure 38 which shows the five year plan of the three disciplines and their expected results.

The Configuration Aeroelasticity FY 83 accomplishments listed below are highlighted by figures 39 through 50.

Aircraft Aeroelasticity:

- Effects of New Fuel Tanks and Non-Jettisonable Pylons on F-16 Flutter Characteristics Determined in TDT
- Transonic Flutter Studies of Effect of Winglets Extended to Twin-Engine Transport Type Wing
- Galileo Parachute Configuration Tested in TDT
- Decoupler Pylon Flight Test Configuration Cleared in TDT
- Transonic Body-freedom Flutter on a Forward-Swept-Wing Model Measured in TDT
- TDT Used to Evaluate Model for Flutter Testing in High Reynolds Number 0.3-Meter Transonic Cryogenic Tunnel
- Effects of New Amraam Missiles on F-16 Flutter Characteristics Studied in TDT

Rotorcraft Aeroelasticity:

- Hingeless Rotor Experiments Validate Analytical Method
- Closed-Loop Flight Test Demonstrates Higher Harmonic Control (HHC) System Effective in Reducing Helicopter Vibrations
- Validated Parameterized Aerodynamics Procedure Developed for Rotor Blade Dynamic Stall Analysis

Rotorcraft Vibrations:

- CH-47D Measurement/Analysis Correlation Enhances Confidence in Use of Finite Element Models for Predicting Helicopter Airframe Vibrations
- Correlation of Analytical and Experimental Vibration Characteristics of Full Scale Helicopter Blades Rotating in a Vacuum

Each highlight is accompanied by descriptive material.

PUBLICATIONS

The FY 83 accomplishments of the Loads and Aeroelasticity Division resulted in a number of publications. The publications are listed below and are identified by the catagories of journal publications, formal NASA reports, conference presentations, contractor reports, and other.

Journal Publications

1. Hajela, P.; and Sobieszszanski-Sobieski, J.: The Controlled Growth Method--A Tool for Structural Optimization (SYN). AIAA Journal, Vol. 20, No. 10, October 1982, pp. 1440-1441.

2. Newsom, J. R.; and Pototzky, A. S.: Analysis and Flight Data for a Drone Aircraft with Active Flutter Suppression. Journal of Aircraft, Volume 19, No. 11, November 1982, p. 1012-1018.

3. Yates, E. C., Jr.; Wynne, E. C.; Farmer, M. G.; and Desmarais, R. N.: Prediction of Transonic Flutter for a Supercritical Wing by Modified Strip Analysis. Journal of Aircraft, Volume 19, No. 11, November 1982, p. 999-1004.

4. Murrow, Harold N.: "Flight Testing" for A/A Highlights Issue. Astronautics and Aeronautics, December 1982, p. 74-75.

5. Kelly, H. N.; Rummler, D. R.; and Jackson, L. R.: Research in Structures and Materials for Future Space Transportation Systems - An Overview. Journal of Spacecraft and Rockets, Volume 20, No. 1, January 1983.

6. Dowell, Earl H.; Bland, Samuel R.; and Williams, Marc H.: Linear/Nonlinear Behavior in Unsteady Transonic Aerodynamics. AIAA Journal, Vol. 21, No. 1, January 1983, pp. 38-46.

7. Edwards, John W.: Flight Test Results of an Active Flutter Suppression System. Journal of Aircraft, Volume 20, No. 3, March 1983, p. 267-274.

8. Molusis, John A.; Hammond, C. E.; and Cline, John H.: A Unified Approach to the Optimal Design of Adaptive and Gain Scheduled Controllers to Achieve Minimum Helicopter Rotor Vibration. Journal of the American Helicopter Society, Vol. 28, No. 2, April 1983.

9. Barthelemy, J.; and Sobieski, J.: Extrapolation of Optimum Design Based on Sensitivity Derivatives. AIAA Journal, Volume 21, Number 5, May 1983.

10. Barthelemy, J.-F. M.; and Sobieszczanski-Sobieski, J.: Optimum Sensitivity Derivatives of Objective Functions in Nonlinear Programming. AIAA Journal (Technical Note), Volume 21, Number 6, June 1983, pp. 913-914.

11. Ruhlin, C. L.; Rauch, F. J.; and Waters, C.: Transonic Flutter Model Study of a Supercritical Wing and Winglet. Journal of Aircraft, Volume 20, Number 8, August 83.

Formal NASA Reports

12. Shore, Charles P.; Nowak, Robert J.; and Kelly, H. Neale: Thermal and Structural Performance of a Flightweight Radiantly and Actively Cooled Panel. NASA TP-2074, October 1982.

13. Bennett, Robert M.: Application of the Zimmerman Flutter-Margin Criterion to a Wind-Tunnel Model. NASA TM 84545, November 1982.

14. Robinson, J. C.: Application of a Systematic Finite-Element Model Modification Technique to Dynamic Analysis of Structures. NASA TM-83292, January 1983.

15. Sandford, Maynard C.; and Ricketts, Rodney H.: Steady- and Unsteady-Pressure Measurements on a Supercritical-Wing Model With Oscillating Control Surfaces at Subsonic and Transonic Speeds. NASA TM-84543, January 1983.

16. Ricketts, R. H.: Structural Testing for Static Failure, Flutter and Other Scary Things. NASA TM-84606, January 1983.

17. Gardner, J. E.: Loads and Aeroelasticity Division Research and Technology Accomplishments for FY 1982 and Plans for FY 1983. NASA TM-84594, January 1983.

18. McCain, W. E.: Comparison of Analytical and Experimental Steady- and Unsteady-Pressure Distributions at Mach Number 0.78 for a High-Aspect-Ratio Supercritical Wing Model with Oscillating Control Surfaces. NASA TM-84589, January 1983.

19. Noor, A. K.; Balch, C. D.; and Shibut, M. A.: Reduction Methods for Nonlinear Steady-State Thermal Analysis. NASA TP-2098, March 1983.

20. Blosser, M. L.: Bending Stiffness of Multiwall Sandwich. NASA TM-84613, April 1983.

21. Adelman, H. M.: Thermal Analysis Research Applicable to Space Station Technology Needs. NASA TM-84658, April 1983.

22. Yeager, W. T.; and Mantay, W. R.: Loads and Performance Data From a Wind-Tunnel Test of Model Articulated Helicopter Rotors With Two Different Blade Torsional Stiffnesses. NASA TM-84573, AVRADCOM TP 82-B-9, April 1983.

23. Deveikis, W. D.: Effects of Flow Separation and Cove Leakage on Pressure and Heat-Transfer Distributions Along a Wing-Cove-Elevon Configuration at Mach 6.9. NASA TP-2127, June 1983.

24. Noor, Ahmed K.; Balch, Chad D.: Hybrid Perturbation/Bubnov-Galerkin Technique for Nonlinear Thermal Analysis. NASA TP-2145, June 1983.

25. Byrdsong, T. A.; and Brooks, C. W.: Wind-Tunnel Investigation of Aerodynamic Loading on a 0.237 Scale Model of a Remotely Piloted Research Vehicle With a Thick, High-Aspect-Ratio Supercritical Wing. NASA TM-84614, June 1983.

26. Edwards, C. L. W.; and Cole, Stanley R.: Predictions of Entry Heating for Lower Surface of Shuttle Orbiter. NASA TM-84624, July 1983.

27. Bolt, Pamela, A.; Hess, Robert W.; and Davis, William T.: Portable Dynamic Pressure Generator for Static and Dynamic Calibration of _In Situ_ Pressure Transducers. NASA TM 85687, August 1983.

Conference Presentations

28. Shore, Charles P.: Application of the Reduced-Basis Method for Nonlinear Transient Thermal Analysis. NASA/GWU Symposium on Advances and Trends in Structural and Solid Mechanics, October 4-7, 1982, Washington, DC. NASA CP-2245, October 1982.

29. Camarda, C. J.; and Basiulis, A.: Radiant Heating Tests of Several Liquid Metal Heat-Pipe Sandwich Panels. Presented at the AIAA 21st Aerospace Sciences Meeting, January 10-13, 1983, Reno, Nevada. (Paper No. 83-0319). NASA TM-84631.

30. Seidel, D. A.; Bennett, R. M.; and Whitlow, W., Jr.: An Exploratory Study of Finite Difference Grids for Transonic Unsteady Aerodynamics. Presented at the AIAA 21st Aerospace Sciences Meeting, January 10-13, 1983, Reno, Nevada. (Paper No. 83-0503). NASA TM-84583.

31. Grosser, W. F.; Britt, R. T.; Childs, C. B.; Crooks, O. J.; and Cazier, F. W., Jr.: Flutter and Steady/Unsteady Aerodynamic Characteristics of Supercritical and Conventional Transport Wings. AGARD-R-703, January 1983.

32. Johnson, E. H.; Hwang, C.; Joshi, D. S.; Harvey, C. A.; and Farmer, M. G.: Adaptive Flutter Suppression--Analysis and Test. AGARD-R-703, January 1983.

33. Newsom, J. R.; Pototzky, A. S.; and Abel, I.: Design of the Flutter Suppression System for DAST ARW-1R - A Status Report. Presented at the AIAA/ASME/ASCE/AHS 24th Structures, Structural Dynamics and Materials Conference, May 2-4, 1983, Lake Tahoe, Nevada. (Paper No. 83-0990). NASA TM-84642.

34. Sobieski, J.; James, B.; and Dovi, A.: Structural Optimization by Multilevel Decomposition. Presented at the AIAA/ASME/ASCE/AHS 24th Structures, Structural Dynamics and Materials Conference, May 2-4, 1983, Lake Tahoe, Nevada. (Paper No. 83-84641). NASA TM-84641.

35. Ricketts, R. H.; Sandford, M. C.; Seidel, D. A.; and Watson, J. J.: Transonic Pressure Distributions on a Rectangular Supercritical Wing Oscillating in Pitch. Presented at the AIAA/ASME/ASCE/AHS 24th Structures, Structural Dynamics and Materials Conference, May 2-4, 1983, Lake Tahoe, Nevada. (Paper No. 83-0923). NASA TM-84616.

36. Bland, S. R.; and Edwards, J. W.: Airfoil Shape and Thickness Effects On Transonic Airloads and Flutter. Presented at the AIAA/ASME/ASCE/AHS 24th Structures, Structural Dynamics and Materials Conference, May 2-4, 1983, Lake Tahoe, Nevada. (Paper No. 83-0959). NASA TM-84632.

37. Turner, C. D.; and Ricketts, R. H.: Aeroelastic Considerations for Continuous Patrol/High Altitude Surveillance Platforms. Presented at the AIAA/ASME/ASCE/AHS 24th Structures, Structural Dynamics and Materials Conference, May 2-4, 1983, Lake Tahoe, Nevada. (Paper No. 83-0924).

38. Chipman, Richard; Rauch, Frank; Rimer, Melvin; and Ricketts, Rodney H.: Transonic Body-Freedom-Flutter Test of a forward-Swept-Wing Model with RSS. Presented at the AIAA/ASME/ASCE/AHS 24th Structures, STructural Dynamics and Materials Conference (Work in Progress Session), May 2-4, 1983, Lake Tahoe, Nevada.

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(Paper No. 83-1027).

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42. Olsen, G. C.; and Smith, R. E.: Analysis of Aerothermal Loads on Spherical Dome Protuberances. Presented at the AIAA 18th Thermophysics Conference, June 1-3, 1983, Montreal, Canada. (Paper No. 83-1557). NASA TM-84656.

43. Wieting, A. R.; Walsh, J. L.; and Bey, K. S.: Aerothermal Environment in Control Surface Gaps in Hypersonic Flow - An Overview. Presented at the AIAA 18th Thermophysics Conference, June 1-3, 1983, Montreal, Canada. (Paper No. 83-1483). NASA TM-84662.

44. Avery, D. E.; Kerr, P. A.; and Wieting, A. R.: Experimental Aerodynamic Heating to Simulated Shuttle Tiles. Presented at the AIAA 18th Thermophysics Conference, June 1-3, 1983, Montreal, Canada. (Paper No. 83-1536). NASA TM-84654.

45. Haftka, R.; and Adelman, Howard: An Analytical Investigation of Shape Control of Large Space Structures by Applied Temperatures. Presented at the VPI&SU/AIAA Symposium on Dynamics and Control of Large Structures, June 6-8, 1983, Blacksburg, Virginia. NASA TM-85649.

46. Sobieski, J.: Structural Optimization: Challenges and Opportunities. Presented at the International Conference on Modern Vehicle Design Analysis, June 22-24, 1983, London, England.

47. Hafez, Mohammed M.; Whitlow, Woodrow, Jr.; and Osher, Stanley J.: Improved Finite Difference Schemes for Transonic Potential Calculations. Presented at the AIAA 6th Computational Fluid Dynamics Conference, July 13-15, 1983, Danvers, MA.

48. Seidel, David A.; Bennett, Robert M.; and Ricketts, Rodney H.: Some Recent Applications of XTRAN3S. Presented at AIAA Applied Aerodynamics Conference, July 13-15, 1983, Danvers, MA. Paper No. 83-1811. NASA TM-85641.

49. Newsom, Jerry R.; and Mukhopadhyay, V.: The Use of Singular Value Gradients and Optimization Techniques to Design Robust Controllers for Multiloop Systems. Presented at the AIAA Guidance and Control Conference, August 15-17, 1983, Gatlinburg, TN. Paper No. 83-2191CP.

50. Mantay, Wayne R.; and Yeager, William T., Jr.: Parametric Tip Effects for Conformable Rotor Applications. Presented at the IAC Ninth European Rotorcraft Forum, September 13-15, 1983, Stresa, Italy. NASA TM-85682.

51. Yeager, William T., Jr.; Mantay, Wayne R.; and Hamouda, M-Nabil: Mechanical Stability of a Hingeless Rotor in Hover and Forward Flight: Analysis and Wind Tunnel Tests. Presented at the IAC Ninth European Rotorcraft Forum, September 13-15, 1983, Stresa, Italy. NASA TM-85683.

52. Wood, G. M.; Lewis, B. W.; Upchurch, B.; Nowak, R. J.; Eide, D. G.; and Paulin, P.: Developing Mass Spectrometric Techniques for Boundary Layer Measurement in Hypersonic High Enthalpy Test Facilities. Presented at the 10th ICIASF, Sept. 20-22, 1983, St. Louis, France.

Contractor Reports

53. Malkus, David S.; Reichmann, Peter I.; and Haftka, Raphael T.: Application of the Hughes-Lin Algorithm to the Two-Dimensional Heat Equation. NASA CR-3599, October 1982.

54. Dechaumphai, Pramote; Thornton, Earl A.: Improved Finite Element Methodology for Integrated Thermal Structural Analysis. NASA CR-3635, November 1982.

55. St. Hilaire, A. O.; and Carta, F. O.: Analysis of Unswept and Swept Wing Chordwise Pressure Data from an Oscillating NACA 0012 Airfoil Experiment Vol. II Data Report. NASA CR-165927, January 1983.

56. Gangwani, Santu T.: Synthesized Airfoil Data Method for Prediction of Dynamic Stall and Unsteady Airloads. NASA CR-3672, February 1983.

57. Gabel, R.; Kesack, W. J.; and Reed, D. A.: Planning, Creating and Documenting a NASTRAN Finite Element Model of a Modern Helicopter, Modeling Documentation Report. Contract NAS1-16460, NASA CR-166077, March 1983.

58. St. Hilaire, A. O.; and Carta, F. O.: Analysis of Unswept and Swept Wing Chordwise Pressure Data From an Oscillating NACA 0012 Airfoil Experiment - Volume I - Technical Report. Contract NAS1-16041, NASA CR-3567, March 1983.

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60. Egolf, Alan T.; and Landgrebe, Anton J.: Helicopter Rotor Wake Geometry and Its Influence in Forward Flight, Vol. II. Contract No. NAS1-14568, NASA CR-3727, April 1983.

61. Gabel, R.; Reed, D. A.; and Ricks, R.: Planning, Creating and Documenting a NASTRAN Finite Element Vibration Model of a Modern Helicopter, Ground Shake Test - Results and Correlation Report. Contract NAS1-16460, NASA CR-116107, May 1983.

62. Barthelemy, Jean-Francois Marie: Development of a Multilevel Optimization Approach to the design of Modern Engineering Systems. NASA CR-172184, August 1983.

63. Liu, W. K.: Mixed Time Integration Methods for Transient Thermal Analysis of Structures. NASA CR-172209, September 1983.

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64. Cazier, F. W., Jr.: Decoupler Pylon Program - Status Review. Presented at the Joint Technical Coordinating Group for Munitions Development 6th Biennial Aircraft/Stores Compatibility Symposium, October 26-28, 1982, White Oak, Maryland.

65. Gilyard, Glenn; and Edwards, John W.: DAST ARW-1 Real Time Flutter Analysis. Presented at the AGARD FMP Symposium on Ground/Flight Test Techniques and Correlation, October 11-14, 1982, Cesme (Altin Yunus), Turkey.

66. Sobieszczanski-Sobieski, J.: From a 'Black Box' to a Programming System. In: Foundation of Structural Optimization: A Unified Approach, John Wiley & Sons, November 1982.

67. Kelly, H. Neale: Recent Experience and Planned Modifications of the Langley 8-Foot High Temperature Tunnel. Presented at the 59th Semi-Annual Meeting of the Supersonic Tunnel Association, April 6-8, 1983, Colorado Springs, Colorado.

68. Sobieski, J.: Introduction to Optimal Design. Presented at the 39th American Helicopter Society Annual Forum and Technology Display, May 9-11, 1983, St. Louis, MS.

69. Cole, S. R.: Determining Reynolds Number Effects on Flutter. Presented at the Va. Academy of Science Annual Meeting, May 17-20, 1983, George Mason University.

70. Ricketts, Rodney H.: Making Your Airplane Safe From Flutter. Presented to Annual Convention of Experimental Aircraft Association, Oshkosh, WI, July 30 - August 5, 1983.

FY 84 PLANS

The FY 84 plans for the Loads and Aeroelasticity Division are broken out by each of the branches (technical areas) and selected highlights of proposed FY 84 milestones are presented.

Aerothermal Loads Branch

For FY 84, there will be a continuing or increasing level of activity in all four disciplines.

TPS Concepts - The main Aerothermal Loads Branch effort in development of durable TPS in 1984 will be directed toward documenting the testing of the titanium and superalloy panels and the Advanced Carbon Carbon (ACC) multipost concept for application where vehicle surfaces exceed the use temperature of the metallic panels. The metallic panels have been exposed to static heating, wind tunnel, vibration, acoustic, and lightning strike tests and will be exposed to foreign object damage and water intrusion tests. The proposed testing will provide a verification of durable TPS concepts for a temperature range from 700°F to over 2300°F that are mechanically attached, have no open gaps, and are mass competitive with ceramic TPS currently employed on the Space Shuttle. Preliminary results will be presented at the NASA Symposium on "Recent Advances in TPS and Structures for Future Space Transportation Systems", NASA Langley Research Center, Hampton, Virginia, December, 13-15, 1983. Work will continue on fabrication of an array of curved superalloy honeycomb prepackaged panels to be delivered in May 1984 for testing in early 1985.

Thermal Loads - The major thrusts of the thermal loads research effort for FY 84 consists of five specific tasks: 1) results of mass addition film cooling tests of a large 12.5 degree cone will be analyzed to determine the cooling effectiveness of both forward facing and tangential coolant ejection. 2) document the results obtained from tests of the CSTA and continue correlation studies with both finite difference and finite element CFD codes. 3) Experimental results of flat TPS tile gap heating as a function of flow angularity will be documented and a tile gap model will be fabricated to fit the CSTA to study the effects of large pressure gradients along curved surfaces on gap heating. 4) A wind tunnel model with shallow spherical protuberances that simulate thermally bowed metallic TPS tiles and a model that simulates a chordwise gap formed between adjacent wing elevons will be tested in the 8' HTT. 5) Generic models will be designed for investigating effects of protuberances submerged within and extended through a turbulent boundary layer and for investigating flow interference effects of inside corners.

Integrated Analysis. - There are two major thrusts for the Aerothermal Loads Branch analysis effort. The first, which complements the thermal loads experimental effort, is the prediction of aerothermal loads. This effort includes continued application of finite difference solutions to complex flow configurations and development of finite element technology for aerothermal load prediction with the long-range goal of developing an integrated flow-thermal-structural analysis capability. Spectral techniques will also be considered in early CY 84. The second, which addresses integrated thermal-structural analysis, includes improvement of techniques, algorithms, and radiation analysis for applications to space transportantion systems and large space structures.

Facilities Operations and Development. - The facilities effort involves the safe and efficient operation and the expansion of the test capabilities of the six high energy facilities of the Aerothermal Loads Branch--the 8' High Temperature Tunnel (8' HTT), 1' x 3' High Enthalpy Aerothermal Tunnel (1' x 3' HEAT), the 7" High Temperature Tunnel (7" HTT), and the 1, 5, and 20 MW Aerothermal Arc Tunnels.

A major thrust will be the verification testing in the 7" HTT of techniques for providing alternate Mach numbers (4, 4.5, and 5) and oxygen enrichment of the methane air combustion products test stream. This effort is in support of a proposed modification (FY 85 CofF) of the 8' HTT which will make it a unique national research facility for testing air-breathing propulsion systems for very high speed aircraft and missiles.

During FY 84 the Superalloy and Titanium TPS, spherical pertuberance models, the Lifting Surface Test Apparatus (LSTA), a one-third scale model of the space shuttle split elevon, and possible DOD programs will be tested in the 8" HTT.

Flow in the test section of the 1' x 3' High Enthalpy Aerothermal Tunnel will be surveyed/calibrated, a new test section panel holder will be checked out and the oxygen enrichment system will be refurbished to permit calibration of high enthalpy flows in late FY 84 and early FY 85.

The test programs during CY 84 for the arc heated tunnels include basic metallic heat shield material evaluation, a basic research program on the

catalysis of recombination of gaseous atoms on metal oxide surfaces, the ACC TPS model evaluation, and if possible, tests for the Space Shuttle project.

Selected highlights of proposed FY 84 milestones are listed below and are shown by figures 51 through 56.

TPS Concepts:
- Curved Metallic TPS
- Advanced Carbon-Carbon Heat Shield Research

Thermal Loads:
- Lifting Surface Test Apparatus
- Chine Gap Heating Test

Integrated Analysis:
- Integrated Fluid/Thermal/Structural Analysis of Structures With Coupled Responses

Facilities Operation and Development:
- 1x3 High Enthalpy Aerothermal Tunnel

Each highlight is accompanied by descriptive material.

Multidisciplinary Analysis and Optimization Branch

There are several major efforts planned for FY 84 which collectively, constitute a concentrated thrust to advance the state of the art of optimization and associated analysis. The focus for optimization algorithms is on development of techniques for optimization of structures under dynamic load for applications more complex than the simple introductory example solved last year (figure 27), and development of an Expert System to assist uses in taking full advantage of the new optimization program (ADS). In structural and multidisciplinary optimization, a major demonstration project--the Lockheed aircraft--will go from the analysis and optimization of the separate subsystems to optimization of the entire assembled system, and three level structural optimization will be demonstrated. In design oriented analysis, a major survey of the existing algorithms will be carried out in order to determine the development directions that might have been overlooked in the existing literature, and installation and documentation of sensitivity capability in a production level program (EAL) is to be completed, and a comprehensive effort to expand sensitivity analysis capability is to be initiated. Research in controlling space structure thermal deformations will be focused on selection of optimal actuator locations. The active controls work will concentrate on tool building for multifunction control systems and on providing support for the DAST ARW-2 experimental programs. In the flight loads area a joint LaRC-DFRF plan for implementing flight testing of ARW-2 will be established and the ARW-2 aircraft will move toward the flight test stage. Specific flight test activities will be formulated. Reporting will begin on results of the spanwise gradient measurements of atmospheric turbulance.

Selected highlights of proposed FY 84 milestones are listed below and are shown by figures 57 through 64.

Active Controls:
- Dynamic Behavior of Statically Unstable FSW Aircraft

Design Oriented Analysis:
- Analytical Sensitivity Derivatives for Aerodynamic Performance

Flight Loads:
- ARW-2 Plans

Optimization and Applications:
- Study for Optimization of a Transport Aircraft Wing for Maximum Fuel Efficiency
- ADS - A New General Purpose Optimization Program
- An Expert System to Choose the Best Combination of Options in ADS
- A Generalized N-Level Structural Optimization
- Optimization Techniques Applied to Helicopter Rotor Design

Each highlight is accompanied by descriptive material.

Unsteady Aerodynamics Branch

For FY 84, there will be a continuing level of activity in developing and applying computational finite-difference algorithms for the solution of the nonlinear unsteady fluid flow equations. A major effort will be the continued development and application of the three-dimensional transonic small perturbation code, XTRAN3S. Correlation of XTRAN3S calculations with the large body of unsteady pressure measurements obtained at Langley will point directions for future improvements. Unsteady viscous boundary layer models will be incorporated and evaluated. An unsteady full potential equation code incorporating monotone flux biased differencing will come to fruition. Development of a time accurate Euler equation code will be initiated as well as applications of a two-dimensional Navier-Stokes code. In addition, the efforts on rotor unsteady airloads begun in FY 83 will continue with the incorporation of compressibility and aeroelastic effects.

In parallel with the development of computational methods, the unsteady pressure measurement program will continue to provide experimental data for code validation. Two-dimensional oscillating airfoil data will be obtained at cryogenic temperatures with Reynolds numbers up to 40 million in order to ascertain viscous boundary layer effects. This test will also provide needed experience in cryogenic testing to support unsteady testing in the NTF. Fabrication of a novel 2-D pitching and plunging flutter mount system will provide an apparatus with which airfoil shape and geometry variations may be ascertained.

Selected highlights of proposed FY 84 milestones are listed below and are shown by figures 65 through 69.

Theory Development:
- Development and Application of XTRAN3S
- Unsteady Full Potential Code for Loads Predictions and Aeroelastic Analysis

Aeroelastic Analysis:
- Effects of Airfoil Shape, Thickness, Angle of Attack, and Camber on Transonic Unsteady Airloads

Unsteady Pressure Measurements:
- Oscillating Pressure Measurements on a 2-D Supercritical Wing in the 1/3 Meter Cryogenic Tunnel
- Pitching and Plunging Suspension System for 2-D Transonic Flutter Testing

Each highlight is accompanied by descriptive material.

Configuration Aeroelasticity Branch

For FY 84 the Configuration Aeroelasticity Branch (CAB) will continue its broadly based research program on dynamic and aeroelastic phenomena of aircraft and rotorcraft.

Although a large portion of this work is associated with tests in the Langley Transonic Dynamics Tunnel (TDT) with companion theoretical studies, flight test programs are included as well. Currently two major flight test programs are in progress. These are the Higher Harmonic Control (HHC) program which uses an active control system for rotorcraft vibration reduction and the Decoupler Pylon (DCP) program for passive flutter suppression of wings with external stores. Both of these programs had their beginning with successful tests in the TDT and advanced to the flight test phase to evaluate characteristics which cannot be properly studied in wind-tunnel experiments. Final closed loop tests for the HHC system implemented on an OH-6A helicopter are expected to be accomplished in the coming year. The DCP flight tests using an F-16 airplane will be completed.

With respect to wind-tunnel tests in the TDT, research studies are planned for both rotorcraft and airplanes. The rotorcraft studies will use the aeroelastic rotor experimental system (ARES) and will focus on determining the effects of parametric changes in rotor tip geometry on rotor performance and vibratory loads and on new rotor concepts such as the hingeless rotor. Airplane focused studies include such items as investigations of winglets on the flutter characteristics of multi-engine transport wings, aeroelastic characteristics of long-endurance, high-altitude vehicles, and shock induced oscillations. In addition to research studies, aeroelastic verification tests are planned for the F-16 airplane with a non-jettisonable pylon configuration and for candidate JVX designs. The JVX study is expected to provide significant research results also.

Work will continue in the area of prediction of helicopter vibration characteristics by using finite element modeling procedures. Basic modeling exercises involving the major airframe manufacturers will be initiated. The exercises will be similar to the recently completed CH-47D study but will involve other airframes. In-house and out-of-house coupled rotor-airframe vibration exercises will be started. An assessment of the state-of-the-art in teaching aeronautical structures engineering will be completed.

On-site work associated with increasing the density capability of the TDT will have begun. this work will require the tunnel to be closed down near the end of the fiscal year.

Selected highlights of proposed FY 84 milestones are listed below and are shown by figures 70 through 73.

Aircraft Aeroelasticity:
- Decoupler Pylon Program
- Modifications to Upgrade The Langley Transonic Dynamics Tunnel

Rotorcraft Aeroelasticity:
- Rotorcraft Vibration Reduction

Rotorcraft Vibrations:
- A National Capability to Analyze Vibration as Part of Helicopter Structural Design

Each highlight is accompanied by descriptive material.

CONCLUDING REMARKS

This publication documents the FY 1983 accomplishments, research and technology highlights, and FY 1984 plans for the Loads and Aeroelasticity Division.

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2. Ashley, Holt: On Making Things The Best - Aeronautical Uses of Optimization. J. of Aircraft, Vol. 19, No. 1, January 1980. pp 5-28.
1982

LANGLEY RESEARCH CENTER

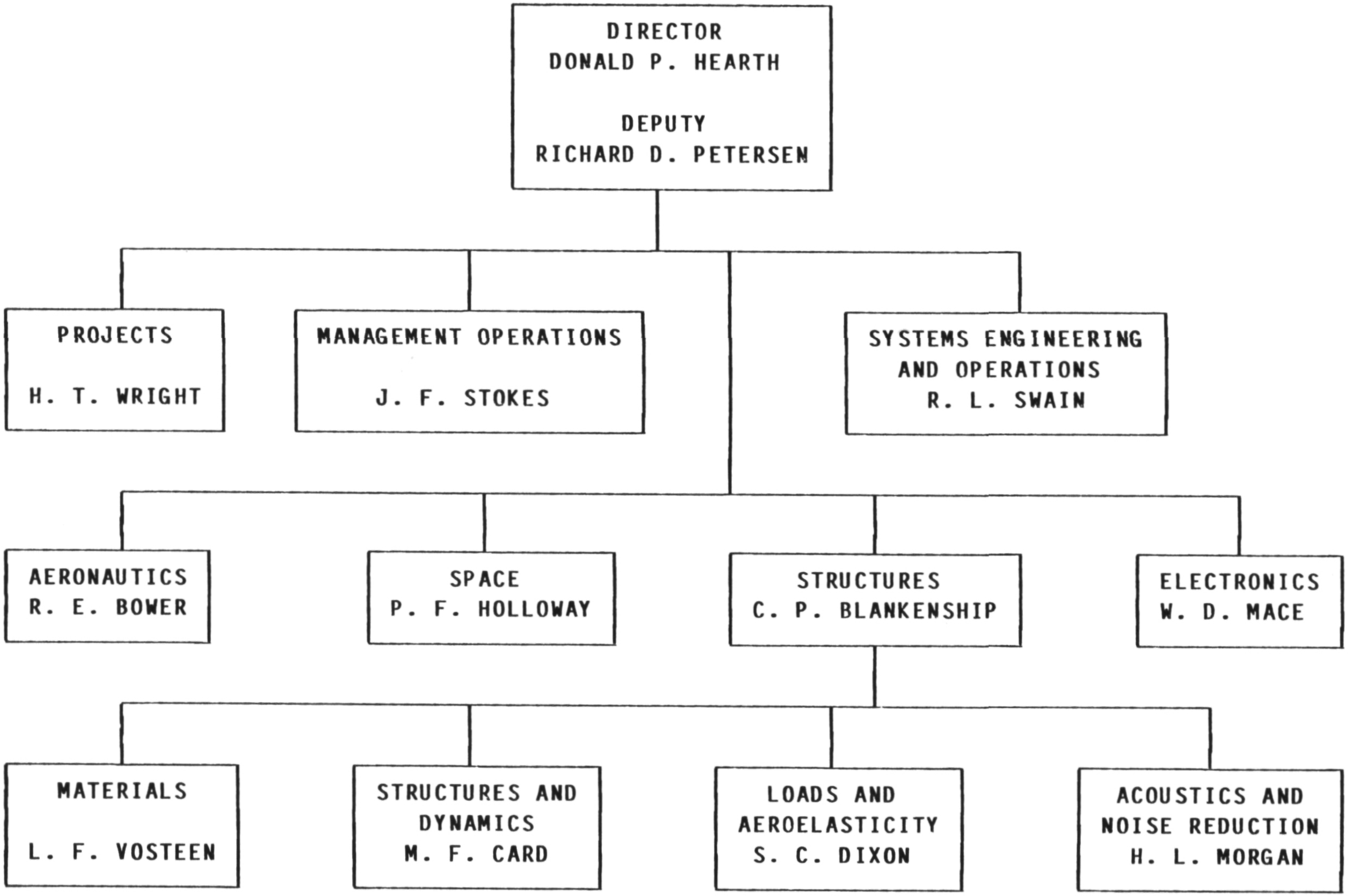


Figure 1.

LOADS AND AEROELASTICITY DIVISION

5

CHIEF: SIDNEY C. DIXON 16
ASSISTANT CHIEF: PERRY W. HANSON 15
CHIEF SCIENTIST: E. CARSON YATES, JR. 15
TECHNICAL ASSISTANT: JAMES E. GARDNER 15

AEROTHERMAL LOADS BRANCH 21	MULTIDISCIPLINARY ANALYSIS AND OPTIMIZATION BRANCH 19	UNSTEADY AERODYNAMICS BRANCH 13	CONFIGURATION AEROELASTICITY BRANCH 14 6A
HEAD: ALLAN WIETING ASST: NEALE KELLY	HEAD: JAROSLAW SOBIESKI 15 ASST: HAL MURROW HDQ. DETAIL : IRVING ABEL 14	HEAD: JOHN EDWARDS 15	HEAD: ROBERT DOGGETT
- TPS CONCEPTS - THERMAL LOADS - INTEGRATED ANALYSIS - FACILITIES OPERATIONS & DEVELOPMENT	- ACTIVE CONTROLS - DESIGN ORIENTED ANALYSIS - FLIGHT LOADS - OPTIMIZATION AND APPLICATIONS	- THEORY DEVELOPMENT - NON-LINEAR AEROELASTIC ANALYSIS - UNSTEADY PRESSURE EXPERIMENTS	- AIRCRAFT AEROELASTICITY - ROTORCRAFT AEROELASTICITY - ROTORCRAFT VIBRATIONS

TOTAL NASA CS - 72
TOTAL ARMY CS - 6

Figure 2.

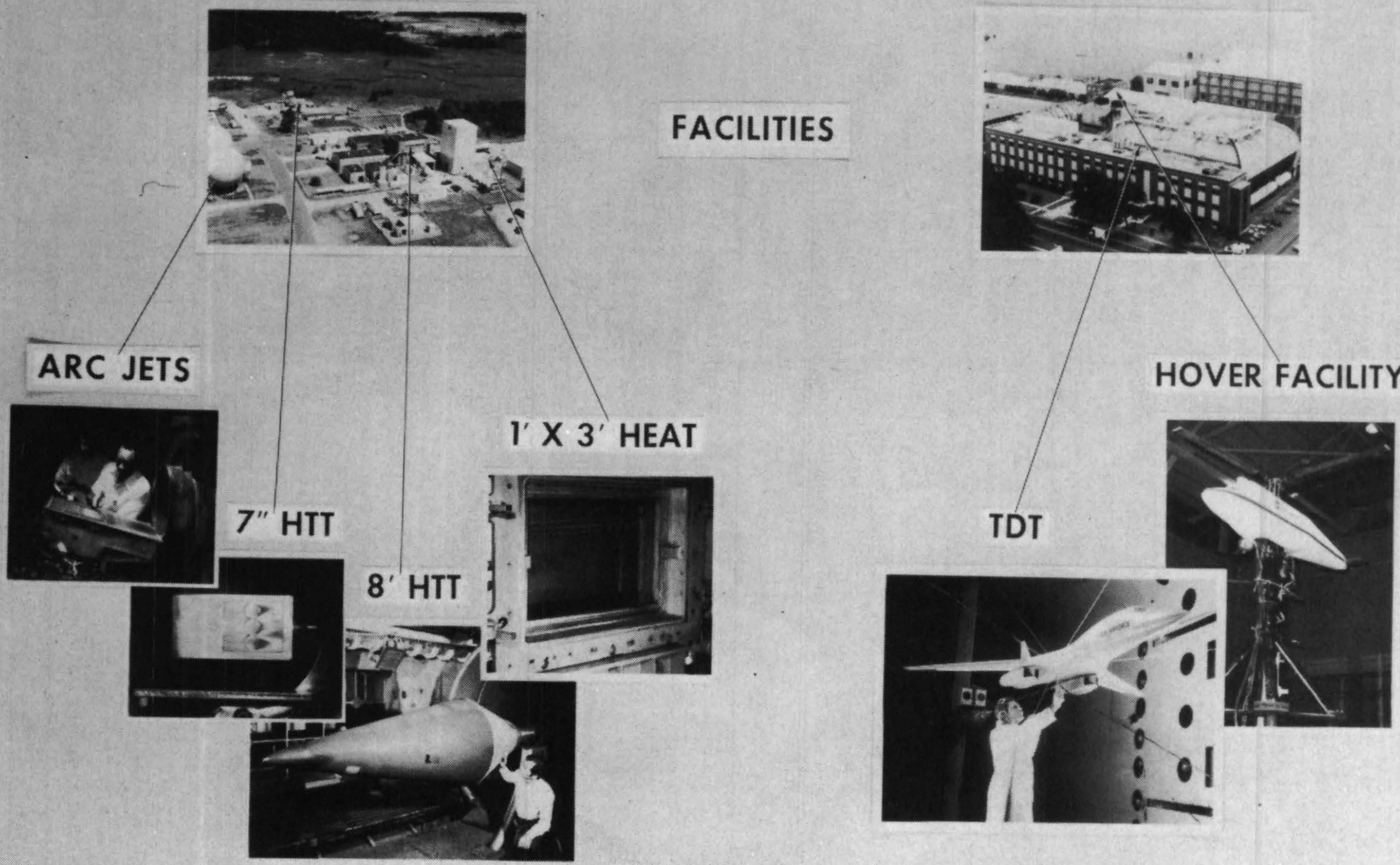
LOADS AND AEROELASTICITY DIVISION

LONG-RANGE THRUSTS

- CONTROL OF AEROELASTIC STABILITY AND RESPONSE
- COMPUTERIZED ANALYSIS AND SYNTHESIS (MULTIDISCIPLINARY OPTIMIZATION)
- THERMAL PROTECTION SYSTEMS FOR ADVANCED STS (CONCEPT DEVELOPMENT, AEROTHERMAL LOADS)
- LIGHTWEIGHT STRUCTURES FOR HIGH-SPEED VEHICLES (AEROTHERMAL LOADS)
- DEVELOPMENT OF ADVANCED STS (AEROTHERMAL LOADS)
- DEVELOPMENT OF LARGE SPACE STRUCTURES (THERMAL LOADS)

Figure 3.

LOADS AND AEROELASTICITY DIVISION



AEROTHERMAL LOADS COMPLEX

TRANSONIC DYNAMICS TUNNEL

FACILITIES

ARC JETS

7" HTT

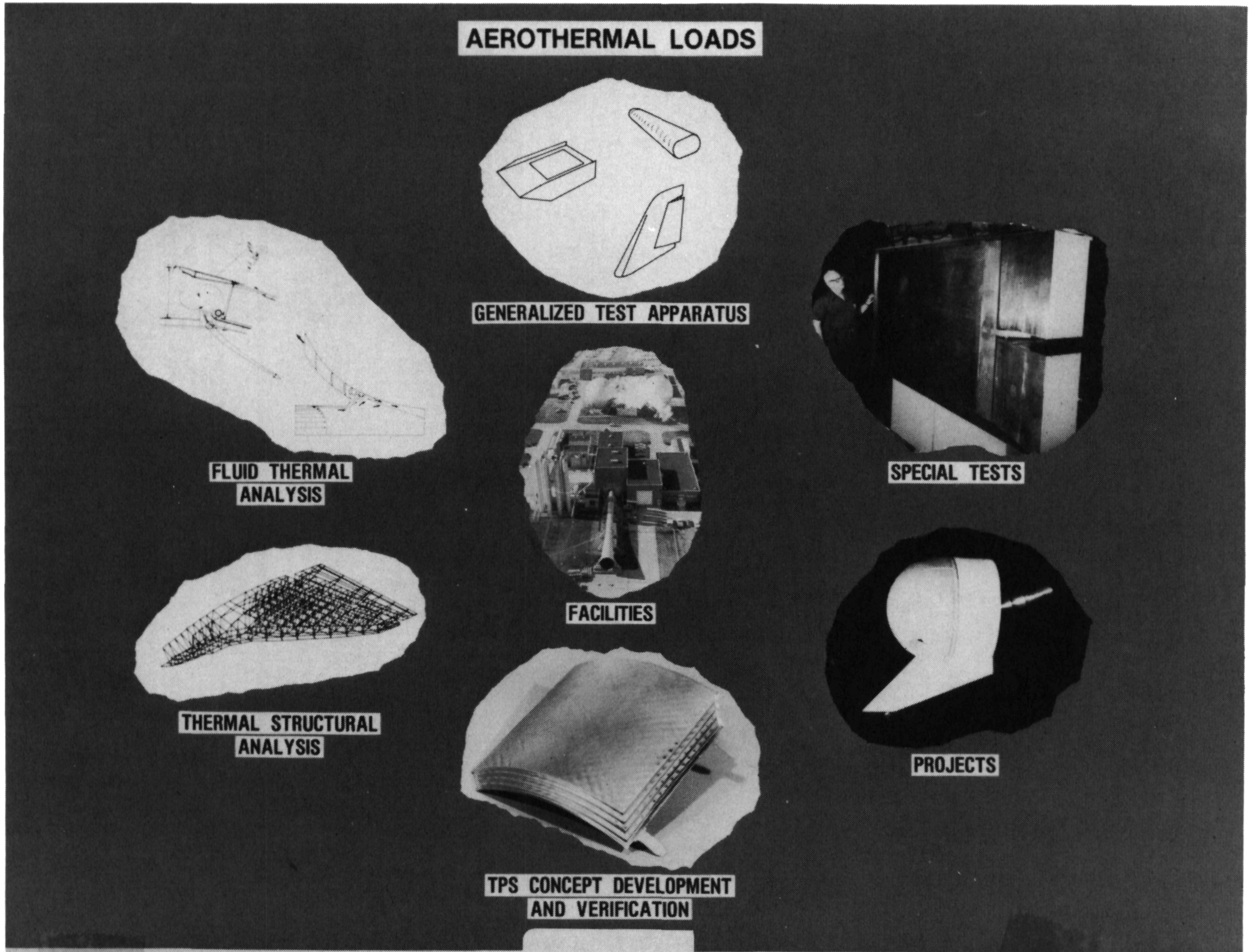
8' HTT

1' X 3' HEAT

HOVER FACILITY

TDT

Figure 4.



AEROTHERMAL LOADS

GENERALIZED TEST APPARATUS

FLUID THERMAL ANALYSIS

SPECIAL TESTS

FACILITIES

THERMAL STRUCTURAL ANALYSIS

PROJECTS

TPS CONCEPT DEVELOPMENT AND VERIFICATION

Figure 5.

AEROTHERMAL LOADS
LOGIC DIAGRAM

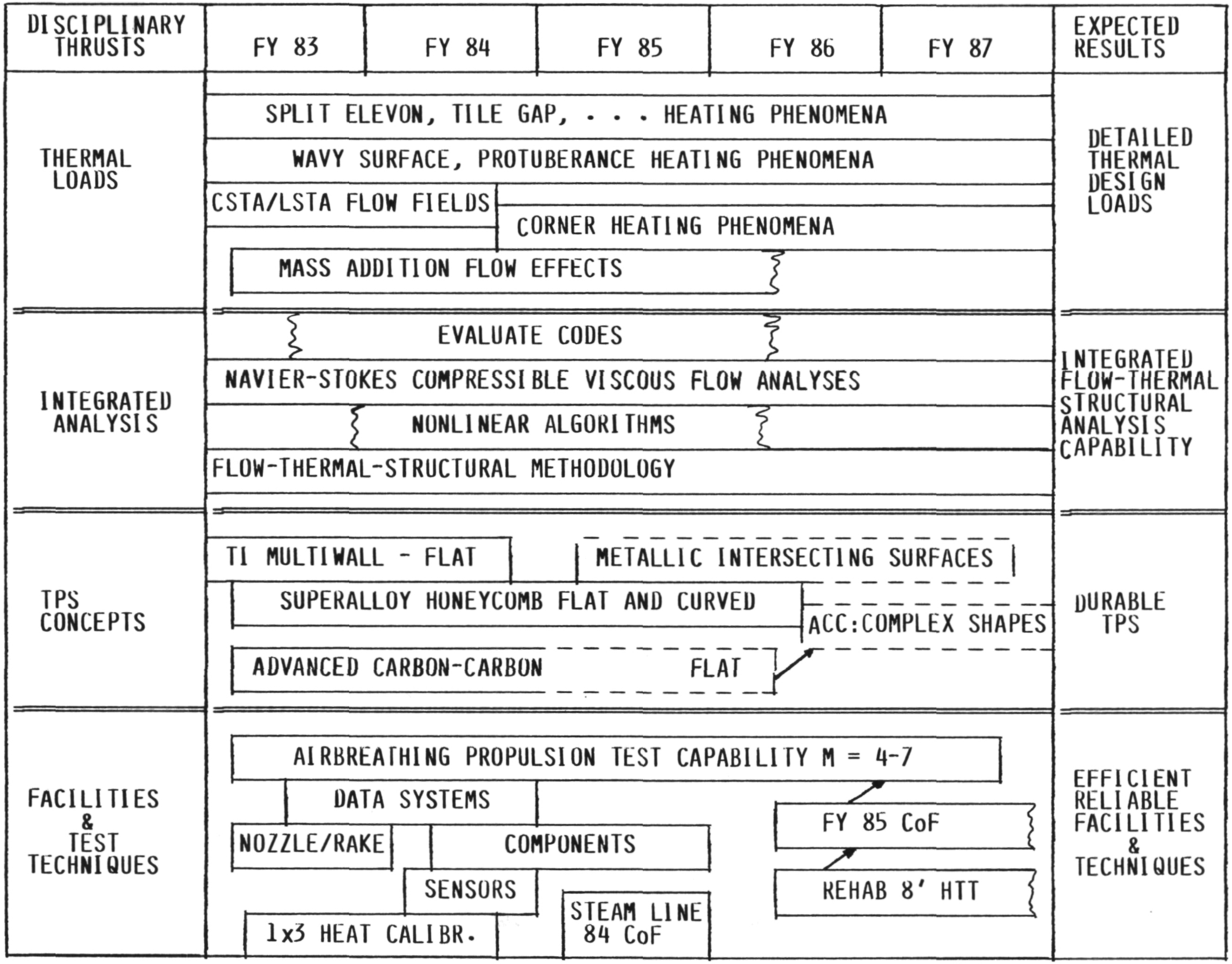


Figure 6.

NON-CATALYTIC COATING FOR METALLIC TPS REDUCES HEATING

Claud M. Pittman
Aerothermal Loads Branch
Extension 3155

RTOP 506-53-33

Research Objective - For the same entry conditions, a metallic surface of an entry vehicle will usually be subjected to a higher heating rate than a non-metallic surface. This difference occurs because metallic surfaces are generally catalytic to the recombination of dissociated air molecules, and the energy of dissociation released during recombination adds to the heat load. A non-catalytic coating will reduce the heat load to the surface and greatly increase the thermal efficiency of the metallic TPS.

Approach - A proprietary ceramic coating marketed by RMF Technologies was evaluated by exposing coated and uncoated Inconel 617 specimens in an arc-tunnel facility using both air and nitrogen-only test streams. The emittances of specimens were measured, and coated specimens were subjected to 80 thermal shock cycles in a 2000°F furnace to evaluate the adhesion of the coating to the metal.

Accomplishment Description - The measured emittance of the coated and uncoated (but oxidized) specimens were 0.65 and 0.8, respectively. The coating remained attached during the thermal shock cycles, and the emittance did not change. The results of the arc-tunnel tests are shown on the attached figure. For the tests in air, arc-tunnel test conditions were established which resulted in a temperature of 1753°F on the uncoated specimen. The coated specimen was tested at the same condition, but reached only 1353°F. Radiation equilibrium heating rates were calculated using the maximum measured surface temperatures and the measured emittances. The heating rate on the coated specimen in air was 37 percent of the heating rate on the uncoated specimen--in nitrogen the heating rate was reduced to 28 percent. Preliminary calculations show about twice as much nitrogen was dissociated in the nitrogen test stream than in air. From these results, nitrogen recombination is the dominant surface catalytic effect.

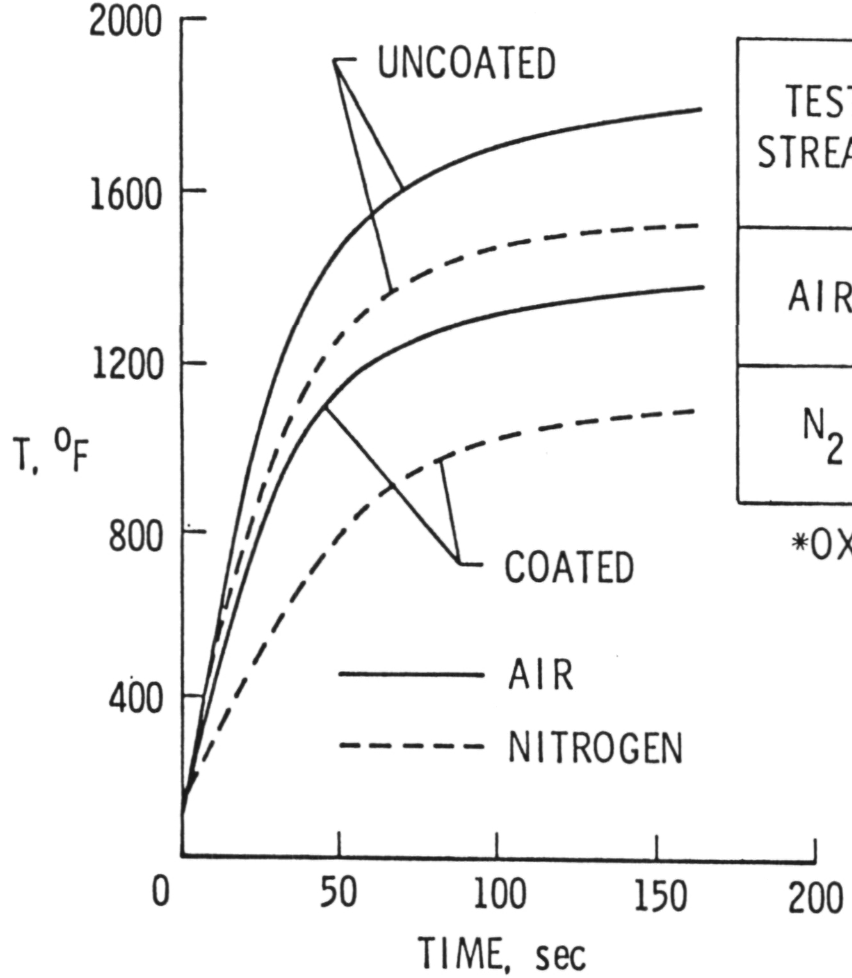
Future Plans - This coating will be applied to several superalloy/honeycomb TPS test panels to be exposed to various wind tunnel, entry heating-pressure, lightning strike, impact damage, vibration and acoustic tests. Modification of the coating composition to increase surface emittance without harming the non-catalytic and adherence characteristics will be attempted. A study to understand the catalytic effect on the atomic recombination of dissociated air has begun using the Center Director's discretionary fund.

Figure 7(a).

NASA
L-83-1,282

NON-CATALYTIC COATING REDUCES HEATING TO METALLIC SURFACES

ARC-TUNNEL TEST RESULTS



TEST STREAM	TEST SPECIMEN INCONEL 617	ENTHALPY, btu/lb	T_{max}, °F	HEATING RATE RATIO
AIR	UNCOATED*	5600	1753	0.37
	COATED	5600	1353	
N_2	UNCOATED*	5000	1495	0.29
	COATED	5000	1045	

*OXIDIZED FOR 2 hrs AT 1800°F IN AIR

Figure 7(b).

PRELIMINARY EVALUATION OF BONDED MW/RSI TILE IS SUCCESSFUL

John L. Shideler
Aerothermal Loads Branch
Extension 3423

RTOP 506-53-33

Research Objective - Damage has occurred on the upper surface of the Shuttle body flap and has required repair after each of flights 4, 5, and 6. The cause of the damage is believed to be impingement of exhaust products from vernier engines. Because these engines are expected to run 2 to 3 times longer during the flight of STS-9, JSC has considered other tile designs for this area to improve durability. One such design consists of titanium multiwall (MW) bonded to a shortened RSI tile (see figure). Preliminary evaluation of this design, in particular the bonded joint, was necessary before the design could be seriously considered because previous MW development has been for mechanical attachments.

Approach - Two test tiles, one is shown in the figure, were fabricated and tested. A strain isolation pad (SIP) was bonded between the MW and RSI to accommodate the thermal deformation of the MW. After proof pull flatwise tension tests to verify acceptable bond joints, the tiles were exposed to heat cycles using a quartz lamp heater to simulate the upper body flap surface temperature history. After the thermal tests, proof pull tests were repeated.

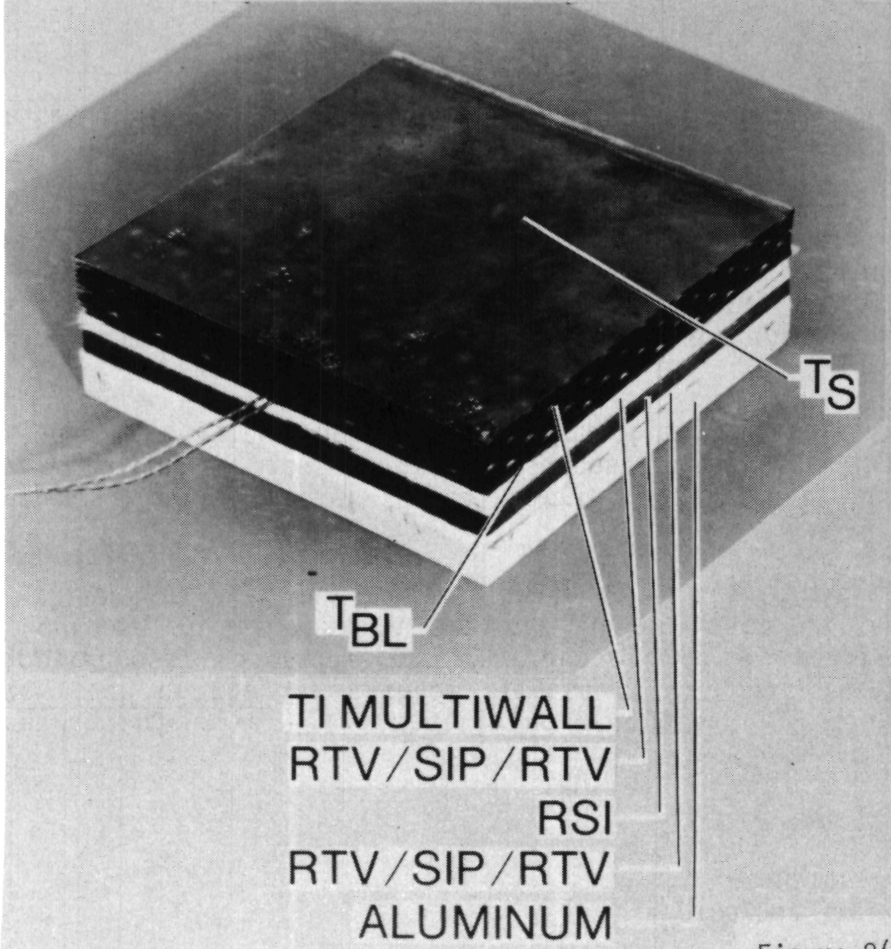
Accomplishment Description - The results of the thermal and proof pull tests were considered successful by both the Langley and JSC technical personnel. Each specimen was exposed to a 10 psi proof pull and to 5 ascent thermal cycles having a maximum surface temperature of 1000°F. The maximum bond line temperature for each tile was slightly less than 350°F which is well within the allowable temperature for the RTV adhesive. The first tile was subjected to an interim proof pull test of 8.2 psi (vacuum chuck separated) and was then exposed to two 1200°F temperature cycles. The maximum bondline temperature was 385°F which is acceptable. The tile was then subjected to a proof pull of 8.1 psi before the vacuum chuck separated from the tile. The second tile was subjected to a proof pull test which achieved only 6.1 psi because the vacuum chuck damaged the top sheet of the MW. The damage resulted from sandwiching a thermocouple wire between the MW surface and the vacuum chuck.

Future Plans - These results were transmitted to JSC for a Shuttle Orbiter CCB meeting on June 14, 1983 where the concept was not accepted because it was considered not certified for Shuttle flight. The accepted concept, which was a thick layer of RTV adhesive applied to the top surface of a shortened RSI tile, is recognized to have only a 1-mission life. No additional development of the MW/RSI concept is planned unless new interest arises for a Shuttle application.

Figure 8(a).

PRELIMINARY EVALUATION OF BONDED MW/RSI TILE IS SUCCESSFUL

MW/RSI TEST TILE



SEQUENCE OF EVALUATION TESTS

- PROOF PULL
- ASCENT RADIANT HEATING
  - 5 CYCLES, $T_{S_{MAX}}$=1000°F, $T_{BL_{MAX}}$=349°F
  - 2 CYCLES, $T_{S_{MAX}}$=1200°F, $T_{BL_{MAX}}$=385°F
- PROOF PULL

Figure 8(b).

LARC TESTS CERTIFY THERMAL BARRIER AND PRESSURE SEAL

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Extension 3894

RTOP 936-12-40

Research Objective - The Shuttle nose landing gear door thermal barrier has required repair of tiles after each of the first three flights of OV-102. Interim repairs have not demonstrated a life cycle effectiveness. Significant turnaround effort was required to assure a proper door seal after rollout. The purpose of the test in the LaRC 20 Mega Watt Aerothermal Arc Tunnel (20 MW AAT) was to certify the new thermal barrier and pressure seals for a single mission.

Approach - A new thicker thermal barrier, designed by Rockwell International, reduced the systems sensitivity to normal manufacturing variances in the structure. The redesign of the nose landing gear door included relocation and reconfiguration of the pressure seal.

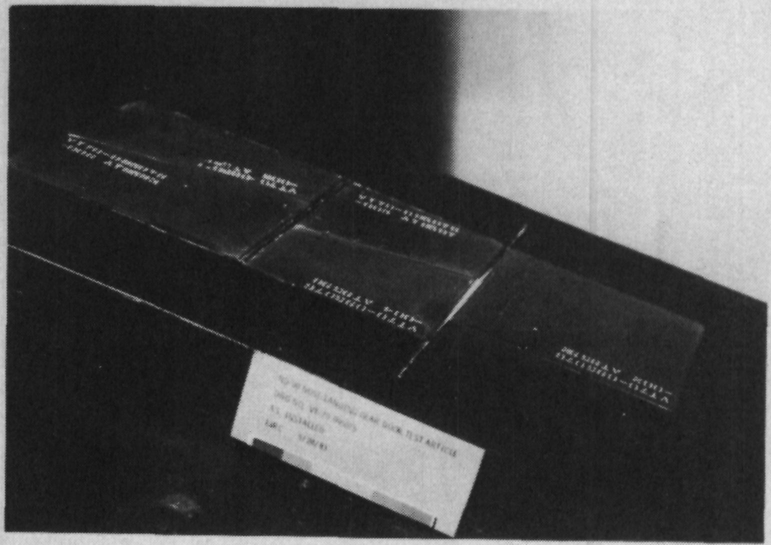
Accomplishment Description - The intertile gaps and steps on the test article duplicated the tolerances that were observed on the actual nose gear door. The test environment simulated the mission and duplicated the previous certification test of the nose landing gear door in the 20 MW AAT. The differential pressures across the thermal barrier and pressure seals were also simulated. All test requirements were met, and the new design certified for a single mission.

Future Plans - At the present time, there are not any additional certification tests planned.

Figure 9(a).

LaRC TESTS CERTIFY SHUTTLE THERMAL BARRIER AND PRESSURE SEAL

- CERTIFIED IN 20 MW AAT FOR SINGLE MISSION
- NOSE LANDING GEAR DOOR COMPONENTS


PRE-TEST

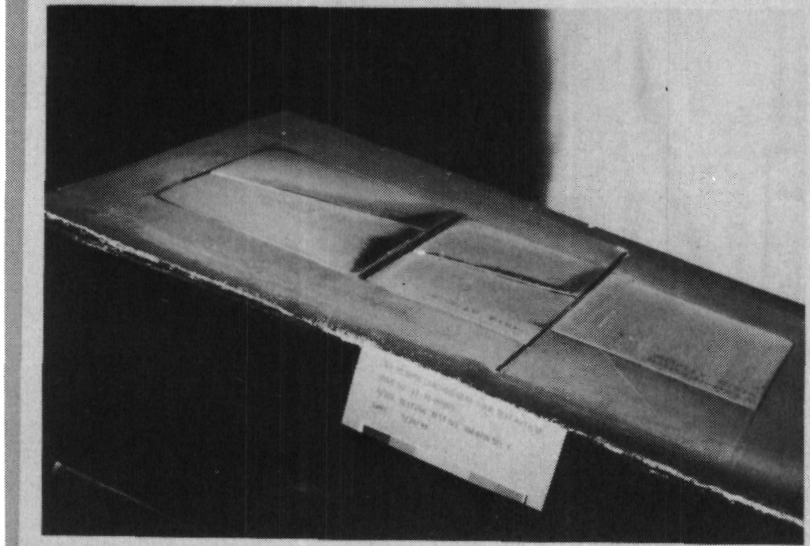

POST-TEST

Figure 9(b).

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AEROTHERMAL TESTS OF METALLIC TPS

John L. Shideler
Aerothermal Loads Branch
Extension 3423

RTOP 506-53-33

Research Objective - The objective is to determine aerothermal performance, particularly heating in the gaps between metallic TPS panels.

Approach - The two 20-panel TPS arrays shown in figure 10(b) were fabricated for aerothermal tests to evaluate the severity of any heating which might occur in the gaps between panels. The arrays were oriented in a "worst case" orientation with the intersections between panels running parallel to the direction of flow.

Accomplishment Description - Both arrays have been tested in the LaRC 8' HTT. Representative results for the superalloy honeycomb array are shown in figure 10(c). Surface temperature and temperature at the bottom of a gap are shown for a test with radiant heating only and for an aerothermal test. During the radiant heating tests, the surface was heated at 1900°F and held constant for about 200 seconds. While the surface temperature was monitored constant, the temperature at the bottom of the gap gradually increased. During the aerothermal tests, the surface temperature is raised to 1900°F by the radiant heaters, and then decreases between the time the heaters are turned off and the time (t = 496 sec) the array is inserted into the aerothermal stream. At this time the surface temperature and the gap temperature both begin rising, and the gap temperature greatly exceeds the temperture measured during the radiant-heating-only test. Those results indicate siginificant gap heating occurs when the array is oriented with panel interesections parallel to the flow.

Future Plans - Aerothermal tests on flat metallic TPS are complete, and aerothermal tests of curved panels are scheduled for FY 85. These panels will have "flow stoppers" at the panel corners in the gaps. Environmental exposure and acoustic tests for the flat panels will be completed in FY 84.

Figure 10(a).

METALLIC TPS ARRAYS FOR 8-FT HTST TESTS

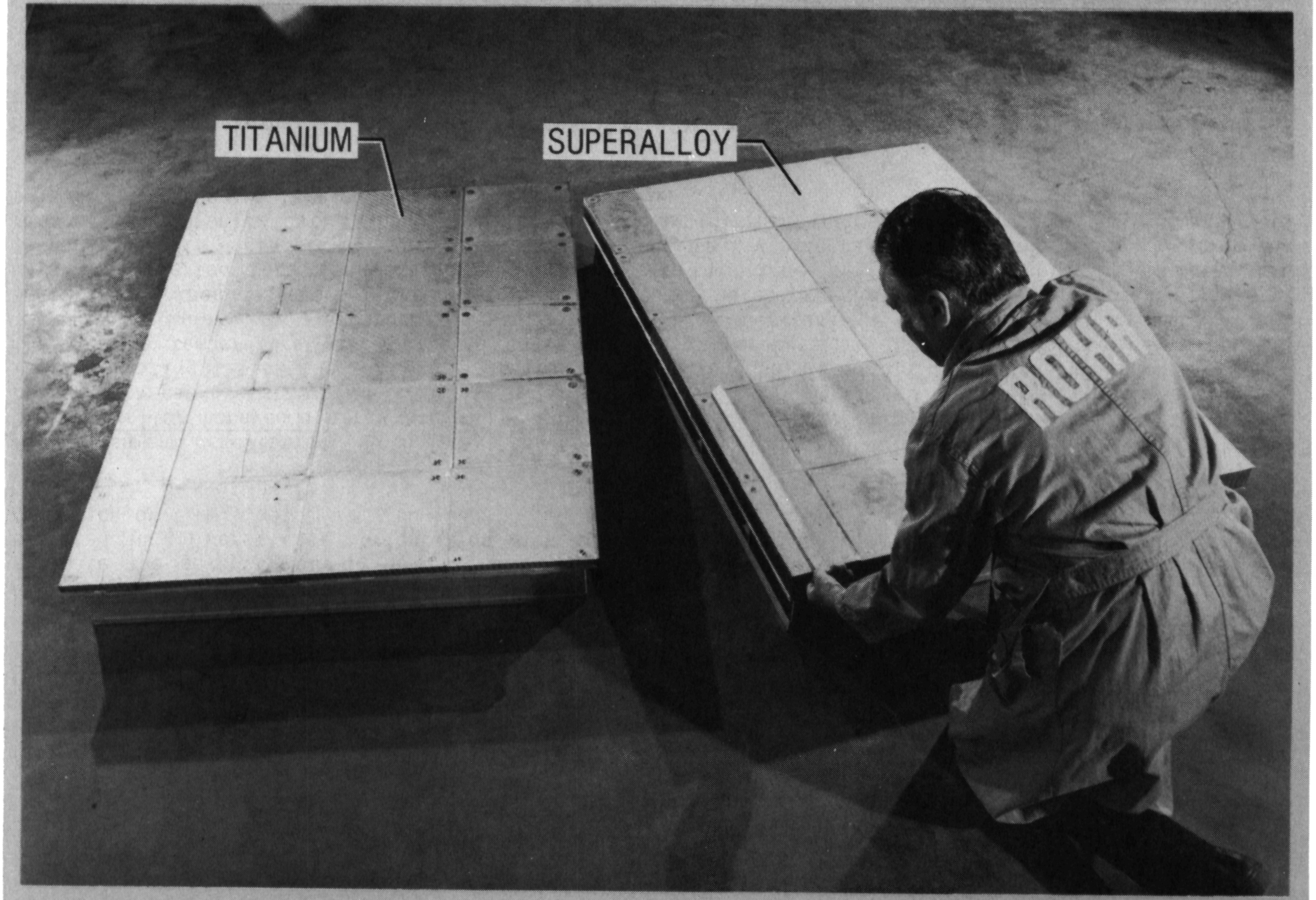


Figure 10(b).

EFFECT OF AEROTHERMAL EXPOSURE ON GAP TEMPERATURE

SA/HC ARRAY

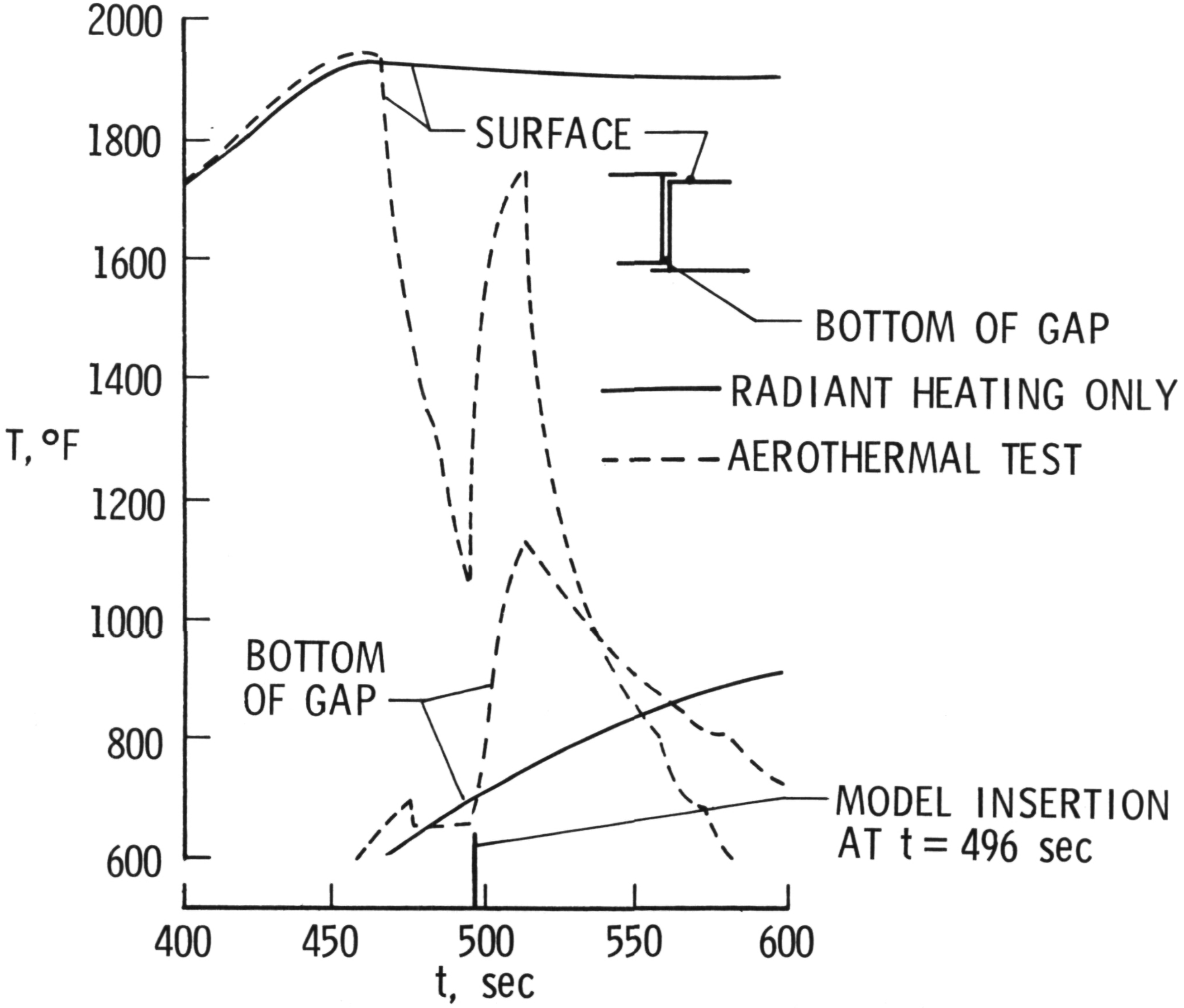


Figure 10(c).

TESTS IN THE 8' HIGH TEMPERATURE TUNNEL SHOW MASS ADDITION FILM COOLING ALTERS THE SHOCK LAYER FLOWFIELD IN ADDITION TO SURFACE PRESSURE AND HEATING

Robert J. Nowak
Aerothermal Loads Branch
Extension 3115

RTOP 506-51-23

Research Objective - Mass addition film cooling (forced injection of a fluid from the surface) is an attractive method of providing thermal protection from hostile aerodynamic heating. Film cooling is an active system that could benefit space transportation and reentry vehicles by supplementing passive thermal protection systems in local areas experiencing excessive heat loads. Although many experimental and analytical studies have been conducted on film cooling, very little experimental data exist for high enthalpy hypersonic flow conditions. Therefore, a test program was conducted in the Langley 8-Foot High Temperature Tunnel to study the cooling effectiveness of both forward facing gas jet and rearward-facing tangential coolant ejection of gaseous nitrogen.

Approach - The tests were done using a 12.5° (half-angle) cone having a 3-ft diameter base. Besides the two nose tips shown in the figure, solid nose tips were used to obtain baseline data with no coolant ejection. Extensive surface instrumentation gave heating and pressure distributions. Shadowgraph and schlieren photographs of the nose region helped define the complex coolant flowfield interaction. Retractable probes at three locations on the model gave shock flowfield Mach number and temperature distributions with and without coolant. Gas samples were taken at the surface and analyzed by an on-line quadrupole mass spectrometer to obtain the coolant/test gas ratio; for these tests, the coolant was seeded with neon.

Accomplishment Description - The shock shape with the gas jet nose was shown to be steady; random perturbations (not shown) of short duration were probably caused by particle ejection. Even far downstream, the shock layer Mach numbers and temperatures were reduced. The gas jet was effective in reducing the surface pressure and the cold wall heating even at 10° angle-of-attack. Mass spectrometer analysis of gas taken through the sample ports confirm the presence of substantial coolant at the surface in the region where heating was reduced.

Future Plans - Reports of the experimental results are in preparation. Gas sampling methods are being refined for tunnel test-stream probing.

Figure 11(a).

TESTS IN THE 8' HIGH TEMPERATURE TUNNEL SHOW MASS ADDITION FILM COOLING ALTERS THE SHOCK LAYER FLOWFIELD IN ADDITION TO SURFACE PRESSURE AND HEATING

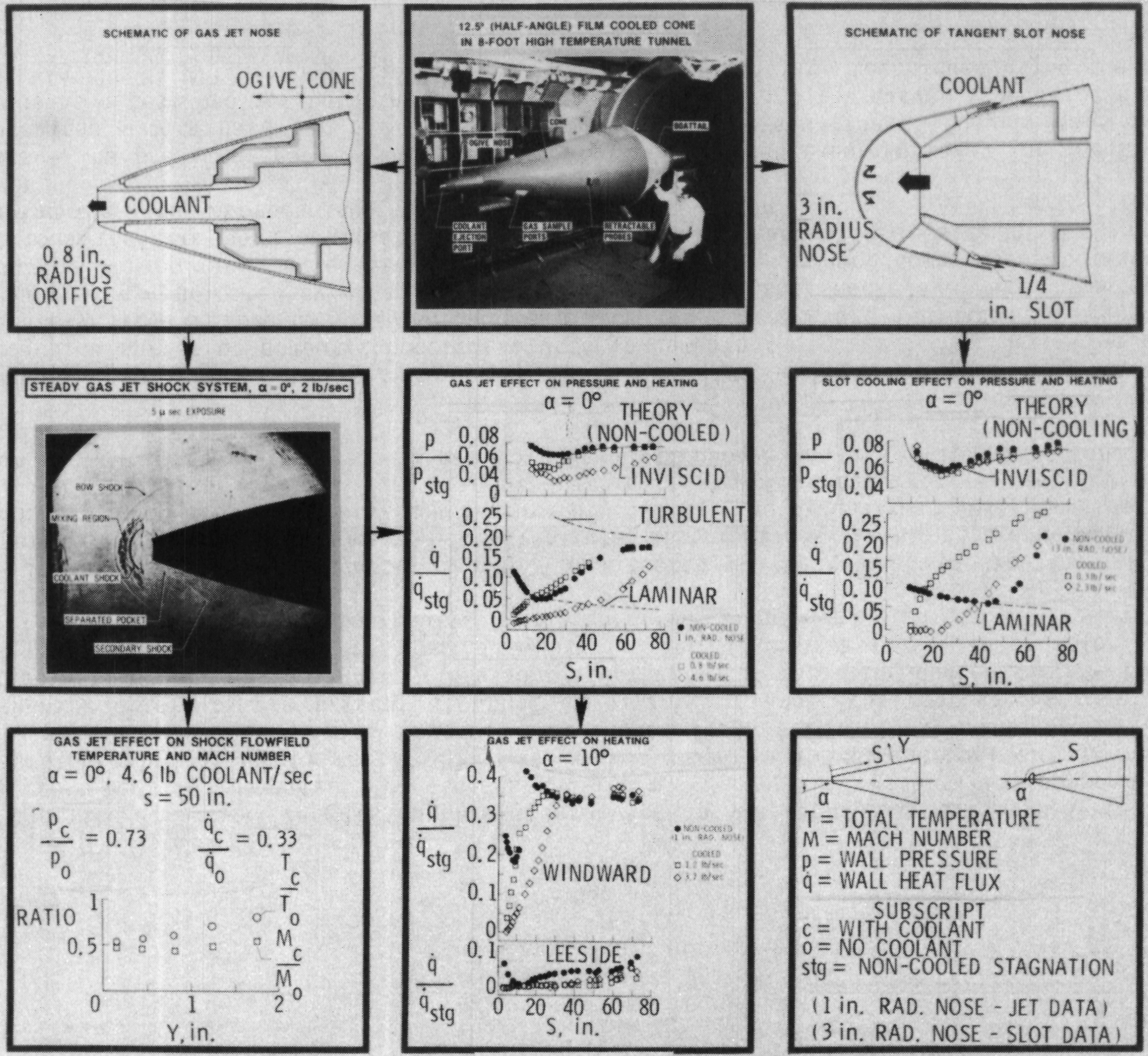


Figure 11(b).

AERODYNAMIC HEATING AND PRESSURE DISTRIBUTIONS ON A BLUNTED THREE-DIMENSIONAL NONAXISYMMETRIC BODY AT MACH 6.8

Cindy W. Albertson
Aerothermal Loads Branch
Extension 3168

RTOP 506-51-23

Research Objective - Generalized test apparatus are used in the Langley 8-Foot High-Temperature Tunnel (8' HTT) as test beds for detailed flow studies and Thermal Protection System (TPS) concept evaluations. Previous aerothermal testing in the 8' HTT has been limited to two-dimensional and axisymmetric flow fields. To extend test capabilities to three-dimensional flow fields, in which large surface pressure and heating-rate gradients are present at angle of attack, an apparatus representative of the forward portion of a lifting body was designed. This apparatus, referred to as the curved surface test apparatus (CSTA), will be used for three-dimensional flow studies and TPS evaluations. In addition, experimental results will be used to compare with results from prediction techniques.

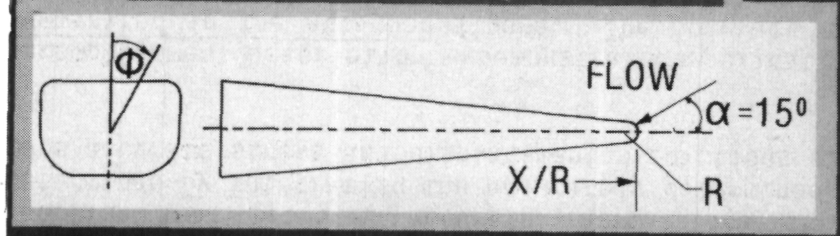
Approach - In support of this research, the CSTA was tested in the 8' HTT to experimentally determine baseline surface pressure and cold-wall heating-rate distributions. The apparatus was tested at a nominal Mach number of 6.8 and a total temperature of 3400°R. The free-stream unit Reynolds numbers were 0.4×10^6, 1.0×10^6, and 1.4×10^6 ft^{-1} and the angle of attack ranged from -20° to +20° in 5° increments. For the data shown, the free-stream unit Reynolds number was 1.4×10^6 ft^{-1} and the angle-of-attack was 15°.

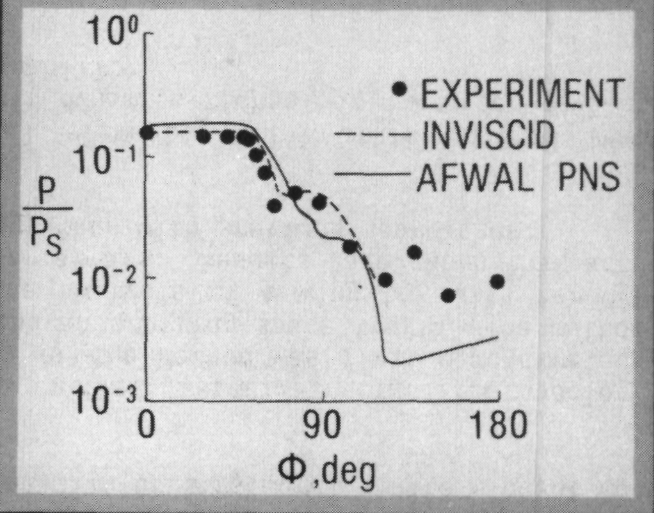
Accomplishment Description - The predictions shown were obtained using two separate approaches. In the first approach, a series of computer codes were used to compute the outer inviscid portion of the shock layer separately from the boundary layer. Results from the approach are indicated by dashed lines. In the second approach, indicated by solid lines, both portions of the shock layer are computed simultaneously using the Parabolized Navier-Stokes (PNS) equations. Preliminary comparisons between experiment and predictions indicate good qualitative agreement. However, accurate leeside predictions cannot be obtained using the first approach due to inviscid-viscous coupling.

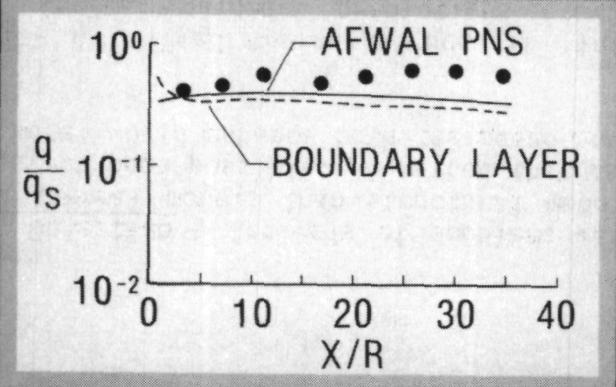
Future Plans - The pressure and heating rate distributions defined experimentally for the CSTA in the 8' HTT have provided a data base for future flow studies and TPS evaluations. Future plans include using the apparatus as a test bed for both the Chine Gap Heating model and the curved superalloy array for wind tunnel tests in the 8' HTT. In addition, the evaluation of prediction techniques using the present data will continue.

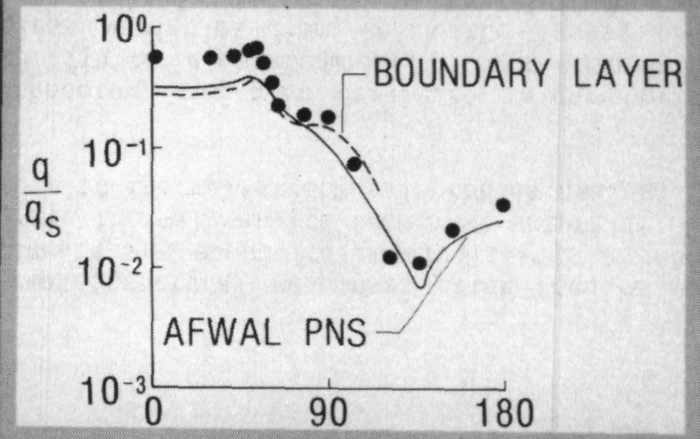
Figure 12(a).

AEROTHERMAL LOADS ON CSTA









WINDWARD MERIDIAN

CIRCUMFERENTIAL DISTRIBUTIONS

Figure 12(b).

UNIFIED THERMAL/STRUCTURAL ANALYSIS

Allan R. Wieting
Aerothermal Loads Branch
Extension 3423

RTOP 506-53-53

Research Objective - Analysis of problems with coupled thermal/structural responses often require more detailed thermal models than structural models. Hence, accurate and economical analysis with a single model has not been possible. A method that can produce accurate thermal results from a structural finite element model would enhance both the speed and accuracy of coupled thermal/structural problem analysis.

Approach - A unified thermal/structural finite element methodology has been developed which provides accurate thermal gradient predictions from the structural finite element model. This methodology utilizes a hierarchy of interpolation functions with nodeless variables from which the lowest order function that provides accurate thermal prediction is automatically selected. Thermal forces are determined by integrating the accurately determined nonlinear temperature distributions. The results are more accurate stress and displacement predictions utilizing the simpler structural finite element model.

Accomplishment Description - Demonstrated applications of the Unified Thermal/Structural methodology are summarized in the attached figure. The accuracy and utility of the method was first demonstrated with one-dimensional elements applied to a scramjet engine strut and an orbiting space truss. The method has been extended to two-dimensional elements and applied to the analysis of a wing box with aerodynamic heating, a curved thermal protection system panel, and to solar arrays. Results have shown that accurate results can be obtained more economically with this methodology than with previous approaches.

Future Plans - Extend the methodology to three-dimensional elements. Join this unified thermal/structural technology to the finite element computational fluid dynamics technology now under development to provide an integrated fluid/thermal/structural analysis capability.

Figure 13(a).

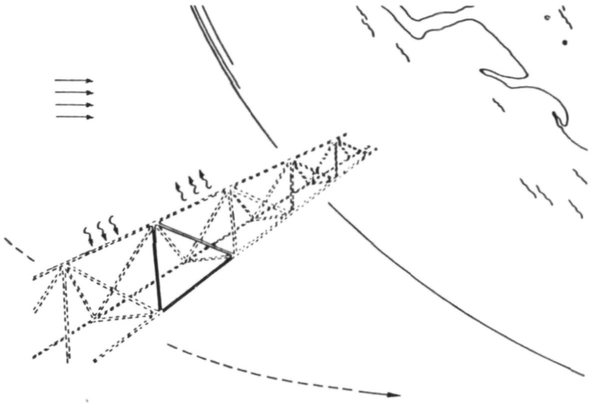
UNIFIED THERMAL/STRUCTURAL ANALYSIS

STATUS

- 1-D ELEMENTS

  DEMONSTRATED ON REAL-WORLD PROBLEMS

  - SCRAMJET ENGINE STRUT
    AIAA 77-187, AIAA 79-1100
  - ORBITING SPACE TRUSS
    NASA CP-2215, AIAA 82-0703



ORBITING SPACE TRUSS

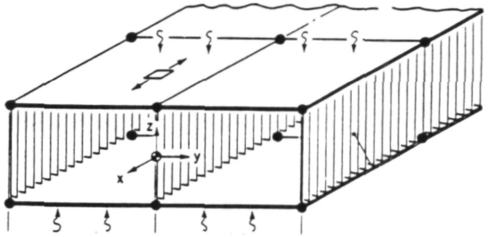
- 2-D ELEMENTS

  DEMONSTRATED ON PRELIMINARY DESIGN PROBLEMS

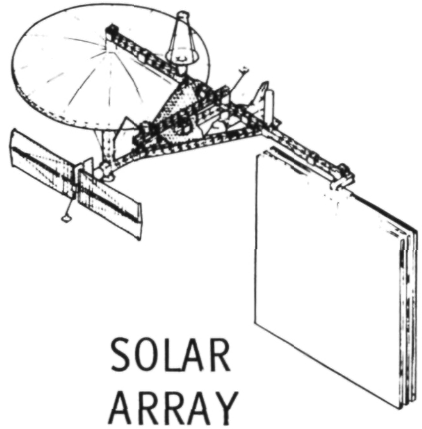
  - WING BOX W/ AERODYNAMIC HEATING
    NASA CR-3635

  BEING EVALUATED ON REAL WORLD PROBLEMS

  - SOLAR ARRAYS



WING BOX



SOLAR
ARRAY

- 3-D ELEMENTS

  TO BE DEVELOPED

OUTLOOK

AN IMPROVED TECHNOLOGY AVAILABLE IN A TIME FRAME TO IMPACT LARGE SPACE STRUCTURE DESIGN

Figure 13(b).

AEROTHERMAL LOADS ANALYSIS OF HIGH SPEED FLOW OVER QUILTED SURFACE CONFIGURATIONS

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Aerothermal Loads Branch
Extension 2325

RTOP 506-53-53

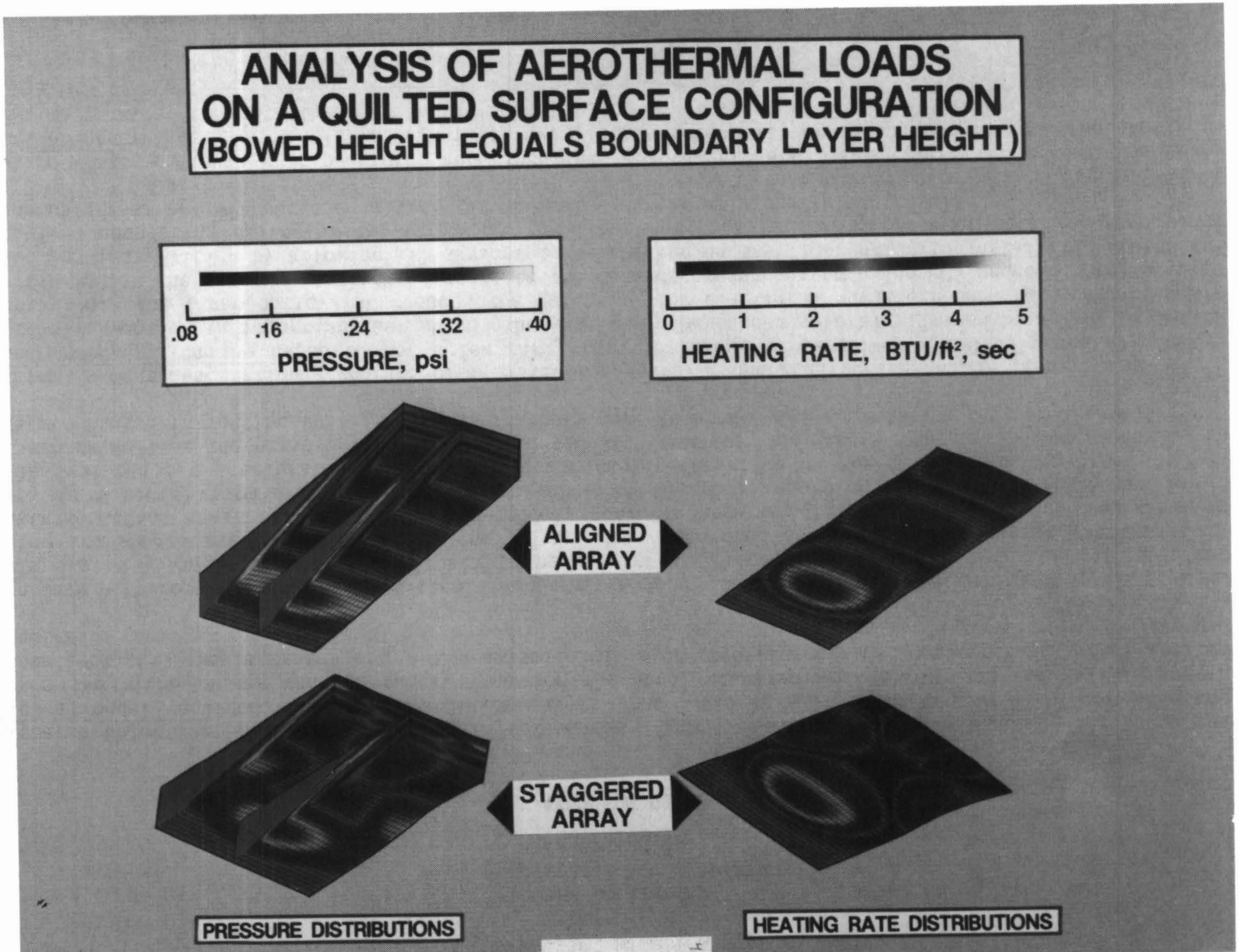
Research Objective - Metallic TPS panels on high speed vehicles are subject to thermal distortions when they experience large through-the-thickness temperature gradients. The panels, anchored at the corners, bow up into the flow field altering a smooth vehicle moldline to a quilted surface configuration. Even though the bowed height of the panels is expected to be less than the local boundary layer thickness, the complex interaction of the high-speed flow field and the bowed surface will effect the local and global aerothermal loads to the vehicle. Accurate analysis requires a detailed 3-D analytical model to capture the nuances of shock formation, 3-D flow relief, vorticity formation, separation, etc.

Approach - Quilted surface configurations simulating bowed TPS panels were modeled for panels oriented normal (aligned array) and at 45 degrees (staggered array) to the flow direction. The physical domains were descritized and mapped into a rectangular-parallelpiped computational domains containing about 80,000 grid points. Flow was modeled with the conservation of mass, momentum (Navier-Stokes), and energy equations in the time-dependent form for laminar flow. Boundary conditions include constant upstream plane data, side symmetry planes, and a no-slip constant-temperature wall. The resulting set of equations was solved with a vectorized MacCormack explicit time-split predictor-corrector algorithm.

Accomplishment Description - Pressure and heating rate distribution results for Mach 7 flow over quilted surface configurations with bowed heights equal the local boundary layer thickness are shown by the color-graphics displays on the attached figure. Leading panel peak pressures increased by 85 percent but downstream panel pressure increases were significantly lower. Leading panel peak heating rates increased by 150 percent, however, total integrated heat loads only increase 44 percent and equivalent maximum radiation equilibrium temperature increased 20 percent. Downstream panel heating was significantly less than leading panel heating. Streaked heating distributions on the staggered array downstream panels are the result of impinging vortices. These data indicate operating temperatures of bowed metallic TPS panels are within the capabilities of the proposed materials and downstream panel integrated heat loads are less than equivalent RSI tiles with gaps.

Future Plans - A turbulence model will be incorporated in the model as well as a variable wall temperature boundary condition to compute the radiation equilibrium temperature of the wall. An experimental program to collect data on quilted surface configurations in the LaRC 8' HTT facility, scheduled for FY 84, will provide comparison data.

Figure 14(a).



ANALYSIS OF AEROTHERMAL LOADS ON A QUILTED SURFACE CONFIGURATION
(BOWED HEIGHT EQUALS BOUNDARY LAYER HEIGHT)

Figure 14(b).

REMOTE MULTIPLEXED DATA SYSTEM WITH FIBER OPTIC LINK PROVEN IN LARC 8-FOOT HIGH TEMPERATURE TUNNEL

Carl R. Pearson
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Extension 3115

RTOP 506-53-33

Research Objective - Research into the effectiveness of mass addition cooling using a 12-1/2° cone (see figure) model required more instrumentation cables than could be placed inside the 8' HTT model sting. Since the nitrogen gas coolant supply line for the model required the majority of the available sting cross sectional area a system with a transmission cable of significantly reduced cross sectional area was required.

Approach - A remote multiplexed system (RMS) with a fiber optic link was designed and built by LaRC. This system allowed 192 channels of data to be sampled at 20 complete frames per second with the data being transfered over a fiber optic link to the data recording equipment. The system conditions the instrumentation sensor signals inside the model, converts them to digital form, and send the resulting data in a serial form over the fiber optic cable to the data recording equipment. The system had to withstand the 2 g acceleration loads which occur during insertion of the model into the free jet test stream as well as the harsh environment associated with testing in a Mach 7 true temperature tunnel. The RMS was housed inside the boat-tail shown in the figure to protect it against the test environment.

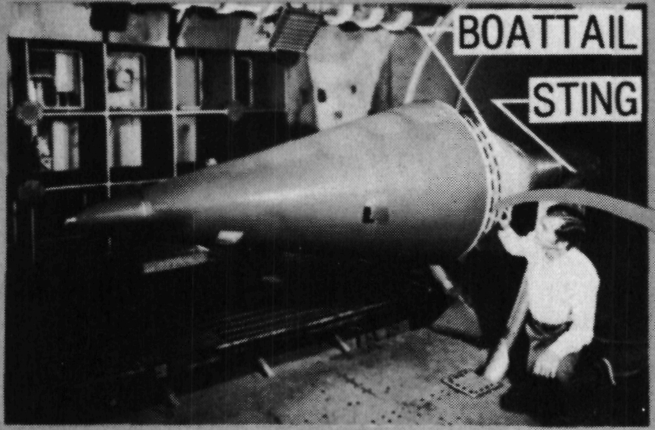
Accomplishment Description - The RMS data system successfully operated during the 57 tunnel tests of the cone model. With the exception of a few early part failures, it performed flawlessly and allowed the accomplishment of an important test which otherwise would have been severely limited by a lack of instrumentation. The fiber optic link reduced the potential for electrical noise and the cross sectional area of cabling in the strut which links sensors to the data recording system. The RMS reduced model preparation and installation by allowing all sensors to be checked on the floor prior to installation. The only required connection during installation was the fiber optic cable. Comparison of data recorded simultaneously with and without the multiplexer indicated essentially equivalent results.

Future Plans - A number of packaging and circuitry improvements are planned which will make this equipment of general use for models in this facility. It has potential for future use in reducing the length of time required to install models in the tunnel.

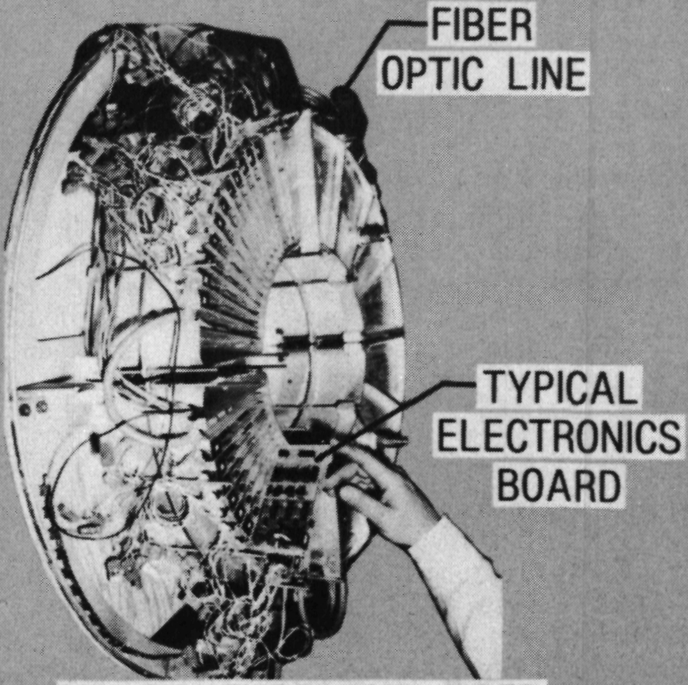
Figure 15(a).

REMOTE MULTIPLEXED DATA SYSTEM WITH FIBER OPTIC LINK

PROVEN IN 8-FOOT HTT



MODEL MOUNTED IN 8-ft HTT



MULTIPLEXER AND FIBER OPTIC LINK
192 DATA CHANNELS

ADVANTAGES

- REDUCED: ELECTRICAL NOISE
  CABLE VOLUME
  MODEL PREP/INSTALLATION
- EQUIVALENT DATA QUALITY

Figure 15(b).

OXYGEN ENRICHMENT AND ALTERNATE MACH NUMBER STUDY OF THE 7" HTT PILOT MODEL FOR THE 8' HIGH TEMPERATURE TUNNEL

Carl Pearson and John R. Karns
Aerothermal Loads Branch
Extensions 3423 or 2154

Research Objective - The 7"HTT pilot effort, for the Oxygen Enrichment and Alternate Mach number modifications for the 8' HTT, is being used to gain experience in the detailed control and operational procedures associated with the planned modifications to the 8' HTT. While in general, the design approaches for these modifications are based on proven technologies, the pilot effort has a significant chance of uncovering problems which could have an impact on the detailed design of the full-scale system. It will also enable the checkout and initial operation of the larger system to progress on a more efficient basis because of the lessons learned with the pilot effort.

Approach/Accomplishments - The oxygen enrichment equipment for the 7" has been designed, installed, operated as a subsystem without the tunnel running, and operated with the tunnel running hot. This effort has pointed out a number of previously unidentified problems such as: the scheduling difficulty in getting parts cleaned for oxygen, the importance of attention to pressure drops in the liquid system, and problems with the insulation planned to be used for the 8 ft. system. A potential problem involving the production of carbon particles during the fuel rich tunnel light-off has been identified but to date has not been found to be a hazard in liquid oxygen.

The fabrication of the Alternate Mach Number equipment for the pilot system is scheduled for completion on 2-1-84. The air supply and electrical controls have been designed and are being installed.

Future Plans - The Oxygen Enrichment System will continue to be operated to gain additional experience, and to obtain a survey of temperature and oxygen distributions in the test stream.

The Alternate Mach Number System is expected to be ready for operational checkout by the end of April 1984.

Figure 16(a).

7" HTT ALTERNATE MACH NUMBER MIXER

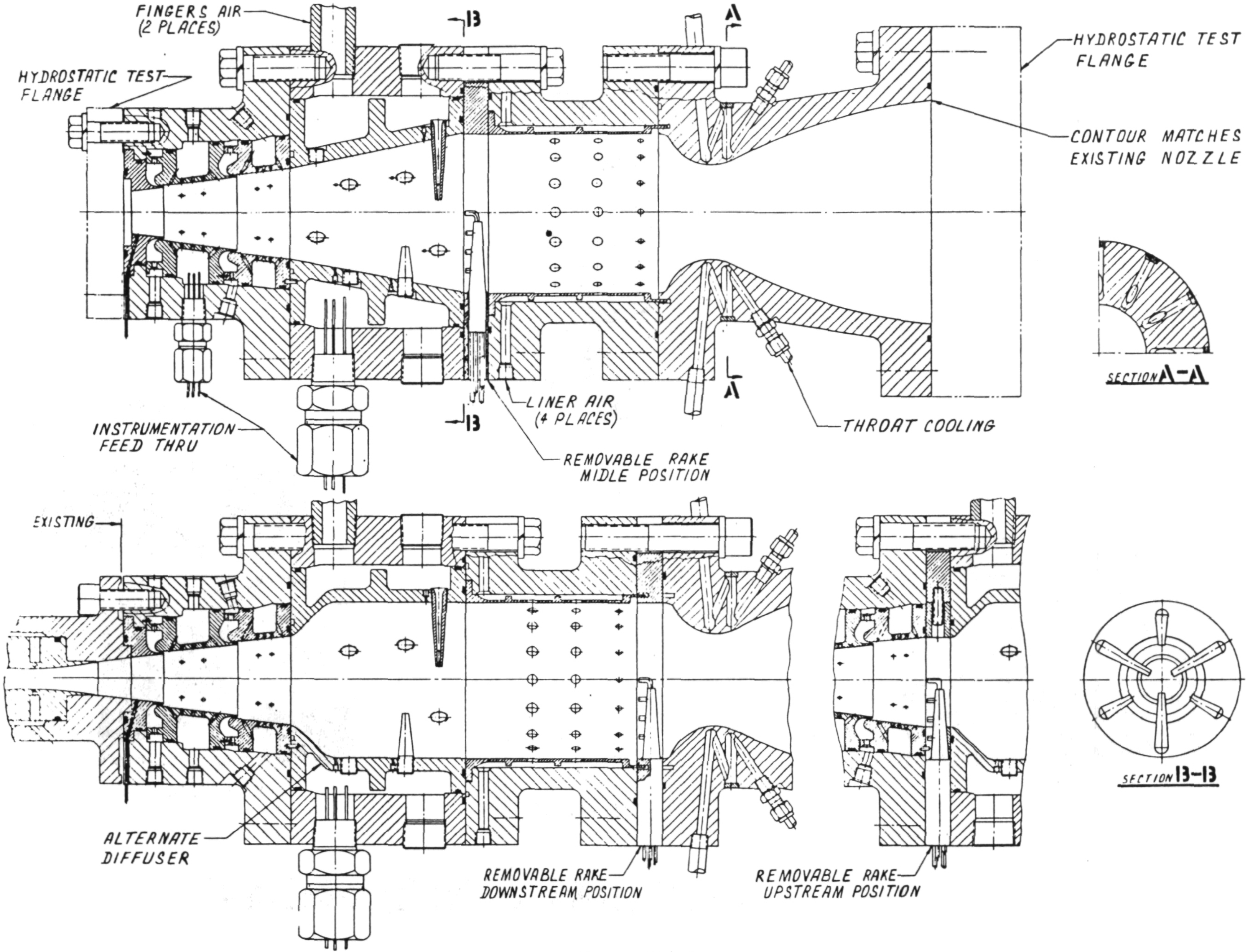
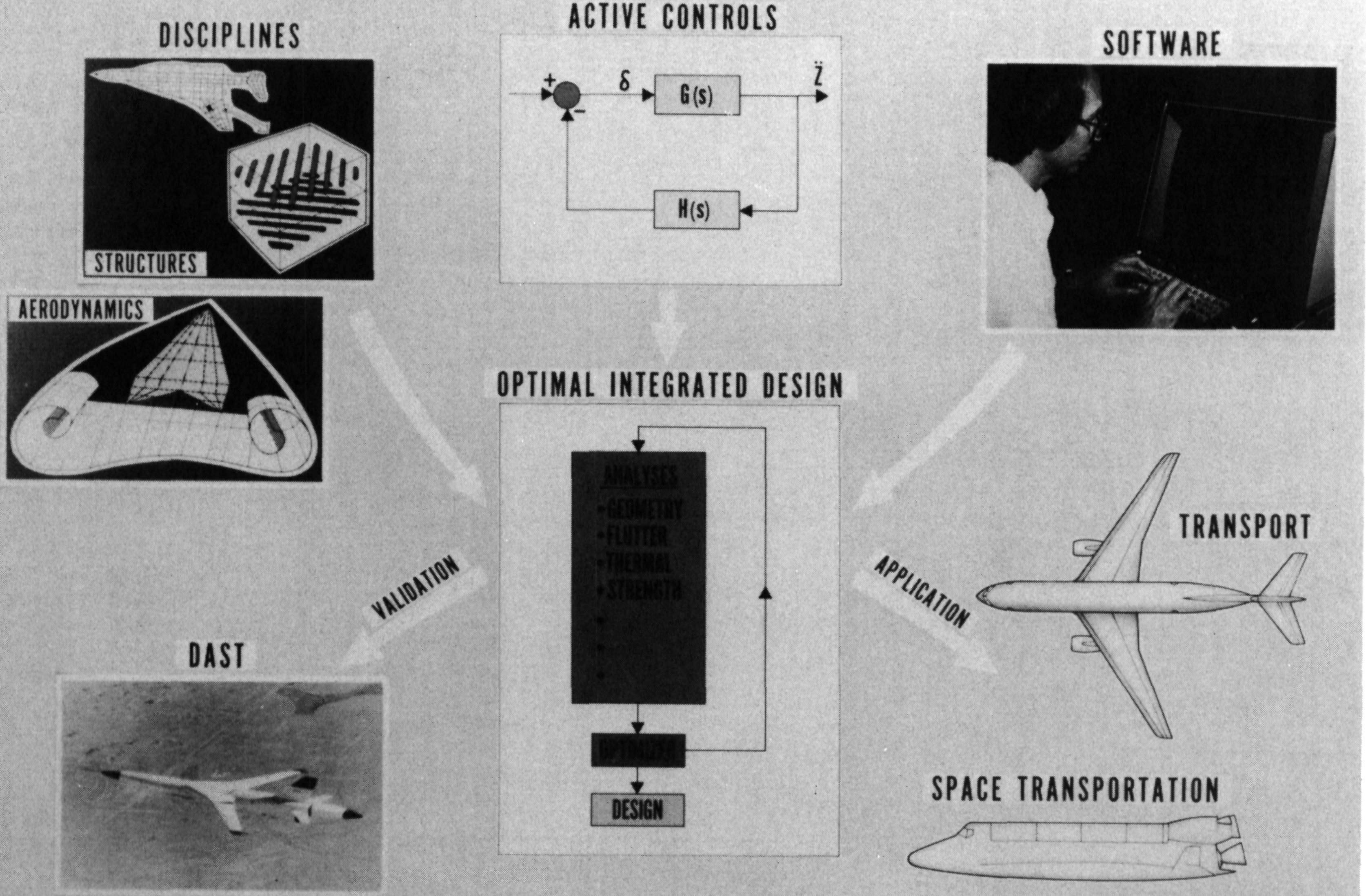


Figure 16(b).

MULTIDISCIPLINARY ANALYSIS AND OPTIMIZATION



DISCIPLINES

STRUCTURES

AERODYNAMICS

ACTIVE CONTROLS

SOFTWARE

OPTIMAL INTEGRATED DESIGN

ANALYSES
- GEOMETRY
- FLUTTER
- THERMAL
- STRENGTH
-
-
-

OPTIMIZER

DESIGN

VALIDATION

APPLICATION

DAST

TRANSPORT

SPACE TRANSPORTATION

Figure 17.

MULTIDISCIPLINARY ANALYSIS AND OPTIMIZATION
FIVE YEAR PLAN

10/84

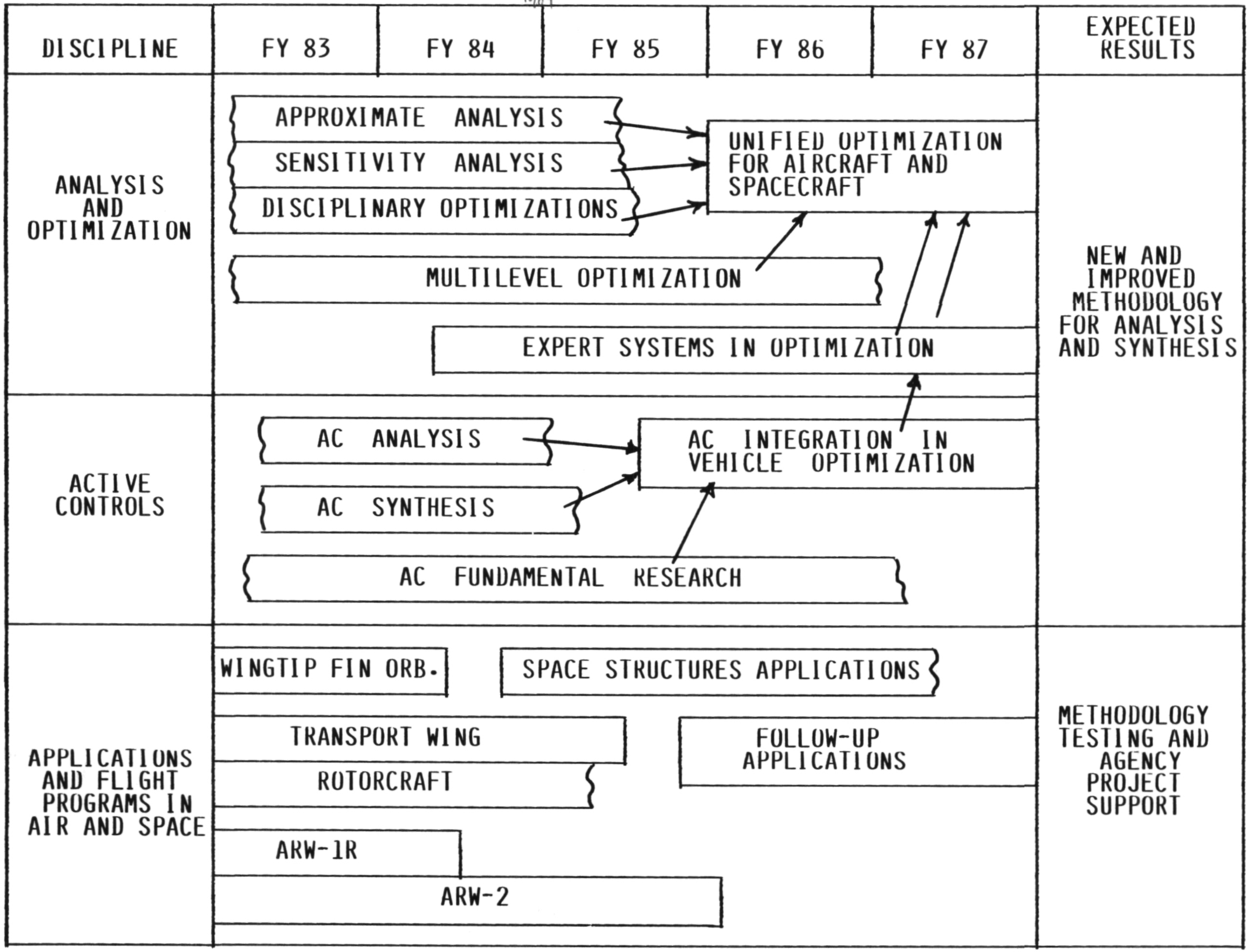


Figure 18.

GLA ANALYSIS METHODS VALIDATION

Boyd Perry
Multidisciplinary Analysis and Optimization Branch
Extension 3323

RTOP 505-33-53

Research Objective - DAST ARW-2, the second research wing for the drone test bed, will incorporate multiple active control systems including flutter suppression, manuever load control, gust load alleviation, and relaxed static stability. The overall objective is to validate the analysis and synthesis methods used to design multiple-purpose, integrated active control systems. The purpose of the present work is to validate gust-loads analysis methods by comparing flight data with analytical prediction.

Approach - The gust load alleviation (GLA) system and the excitation filter have been designed under contract (Boeing Wichita) and are indicated schematically in the accompanying figure. The GLA system uses an outboard aileron on the wing and the all-movable horizontal tail ("GLA surfaces") to reduce loads. Because, during flight testing, it is extremely unlikely to encounter actual atmospheric turbulence of sufficient time duration to collect the required GLA-on and GLA-off data, the following technique will be employed for GLA flight testing: An inboard surface ("artificial excitation surface") will be deflected randomly to generate an artificial excitation which will produce incremental loads on the wing. The artificial excitation is produced by passing white noise through an excitation filter to the inboard surfaces. The characteristics of this artificial excitation are known analytically as are the characteristics of actual atmospheric turbulence. However, with regard to flight testing, the artificial excitation has a significant advantage over actual turbulence in that it can be applied at will by flight test engineers from the control room. The equations and techniques used to represent the actual turbulence analytically can be easily modified to represent the artificial excitation. Therefore, GLA analysis method validation may be achieved through the use of the artificial excitation. The quantity of primary interest in GLA analysis and design is the wing-root bending moment due to gust (or due to artificial excitation).

Accomplishment Description - Analytical results showing the performance of the GLA for both atmospheric turbulence and artificial excitation are presented in the figure. Wing root bending moment is reduced about 30% for atmospheric turbulence and about 50% for artificial excitation.

Future Plans - There are plans at LaRC to resynthesize the excitation filter in-house so that the bending-moment power spectral density function (psd) due to artificial excitation more closely matches the bending moment psd due to gust.

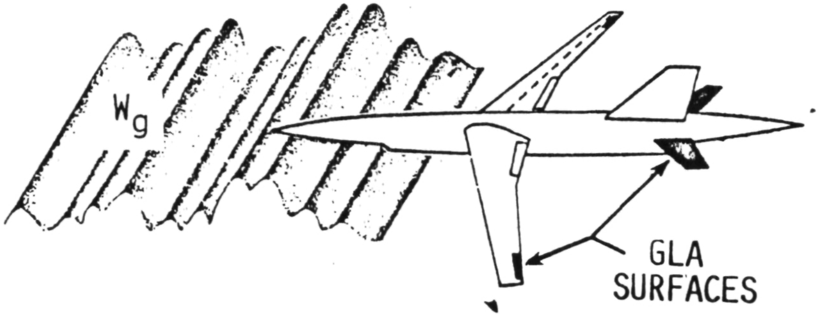
Figure 19(a).

GLA ANALYSIS METHODS VALIDATION

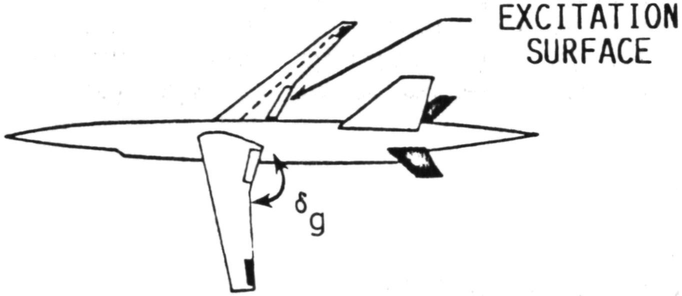
ARW-2 TEST BED

FLIGHT TEST TECHNIQUE

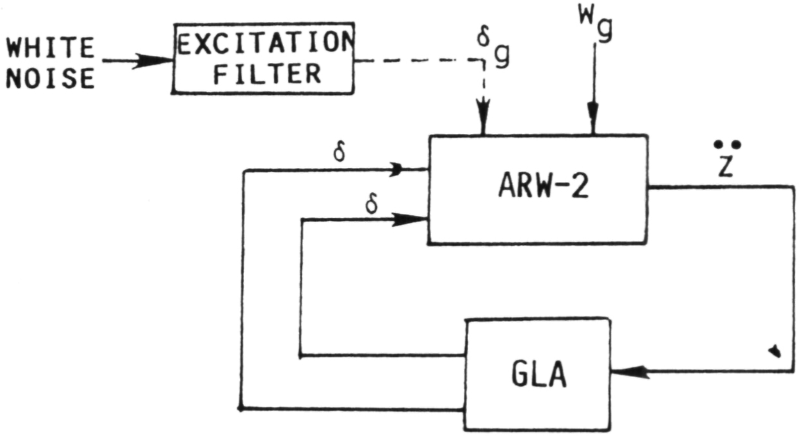
ATMOSPHERIC TURBULENCE RESPONSE



ARTIFICIAL RESPONSE



GLA ANALYSIS



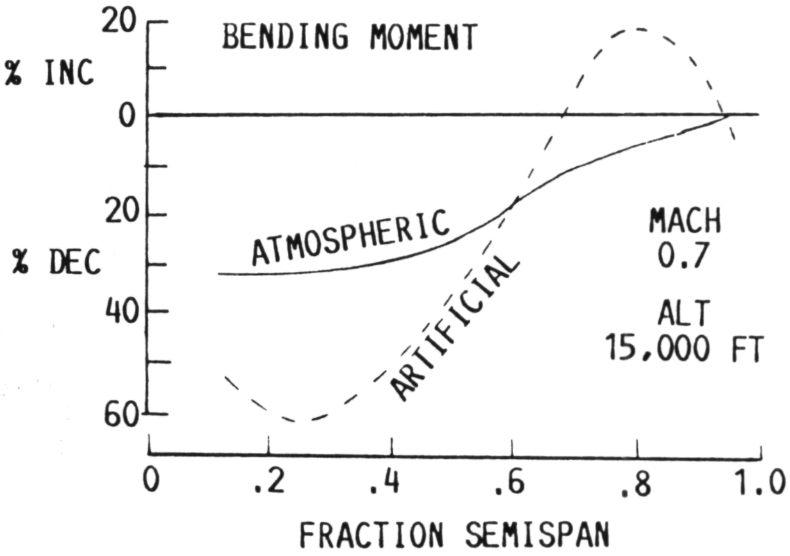


Figure 19(b).

MULTILOOP SYSTEM GAIN AND PHASE MARGIN OPTIMIZATION

Jerry R. Newsom and V. Mukhopadhyay
Multidisciplinary Analysis and Optimization Branch
Extension 3451

RTOP 505-33-53

Research Objective - The guaranteed gain and phase margins of a multiloop system is characterized in terms of the minimum singular value of the system return difference matrix at the plant input. The present objective is to develop a method for designing robust feedback controllers using the singular value properties and numerical optimization schemes.

Approach - Analytical gradients of the singular values with respect to the design variables in the controller are derived. A cumulative measure of the singular values and their gradients with respect to the design variables are used with a numerical optimization technique to increase the system's robustness. The optimization scheme is graphically represented on the left side of the accompanying figure.

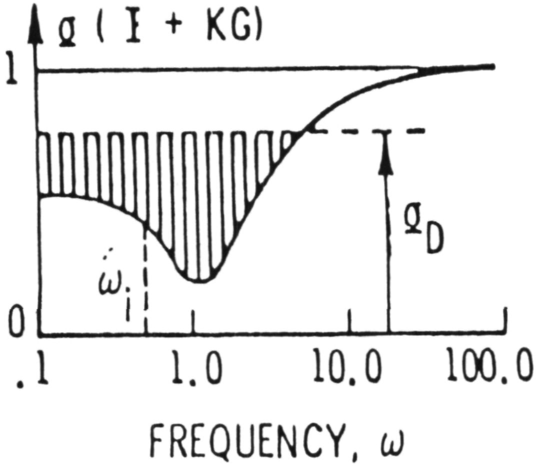
Accomplishment Description - The method is applied to redesign a nominal controller for the ARW-2 lateral altitude control system, having two-inputs and two-outputs. The right side of the accompanying figure shows the result after applying the optimization technique. The minimum singular value is increased from 0.25 to 0.6 resulting in substantial improvement of guaranteed stability margins.

Also, the singular value gradients provide good insight into the system sensitivity due to controller parameter variations.

Future Plans - Generally the robustness optimization scheme results in degraded system response and some loss of high frequency attenuation. A comprehensive overall design scheme will be formulated which includes the responses and robustness at the output as additional constraints.

Figure 20(a).

MULTILOOP GAIN AND PHASE MARGIN OPTIMIZATION



OPTIMIZATION TECHNIQUE

- $F = \sum f_i^2$
- $f_i = \text{MAX}\left\{0, \left[\sigma_D - \underline{\sigma}(j\omega_i, p)\right]\right\}$
- MINIMIZE F

DESIGN RESULTS

ARW-2 LATERAL ATTITUDE CONTROL SYSTEM

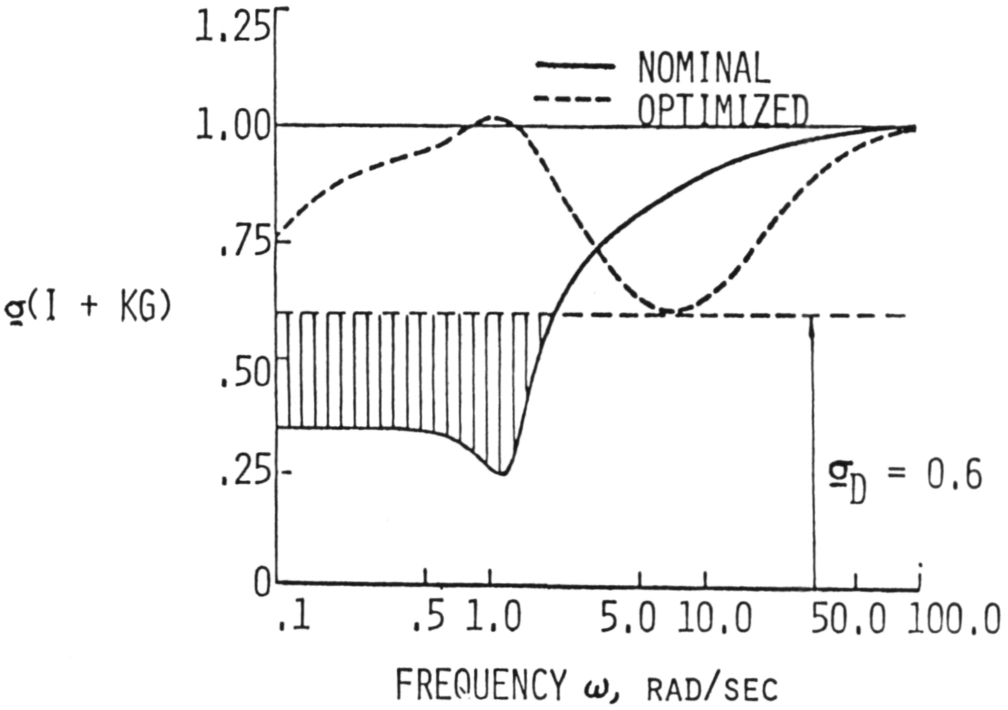


Figure 20(b).

COMPARISON OF EXPERIMENTAL CONTROL SURFACE UNSTEADY AERODYNAMICS WITH DOUBLET LATTICE PREDICTIONS

William E. McCain
Multidisciplinary Analysis and Optimization Branch
Extension 3169

RTOP 505-33-53

Research Objective - The second aeroelastic research wing (ARW-2) in the DAST program incorporates multiple active control systems on a high-aspect-ratio supercritical wing, considered to be representative of an Energy Efficient Transport (EET) configuration. One of the objectives in the DAST program is to evaluate the analysis and synthesis methods used to design multipurpose, integrated active control systems. The present research objective is to compare experimental and predicted control-surface unsteady aerodynamics in order to evaluate the analytical techniques used for calculating the unsteady aerodynamic loads.

Approach - The Doublet Lattice method is used extensively in calculating unsteady aerodynamics within large multipurpose computer programs for active control synthesis and analysis. Since the linear lifting-surface theory of the Doublet Lattice method cannot account for viscous or transonic effects, empirical corrections based on experimental measurements are routinely applied to improve the calculated aerodynamics. A rigid 3-D wind tunnel model of a high-aspect-ratio supercritical semispan wing equipped with oscillating control surfaces, similar to the ARW-2, was tested at LaRC and provided an extensive data base of measured steady and unsteady pressures.

Accomplishment Description - Comparisons were made between the experimental results of the rigid wind tunnel model and Doublet Lattice calculations, for steady and unsteady pressure distributions generated by 2 trailing edge control surfaces.

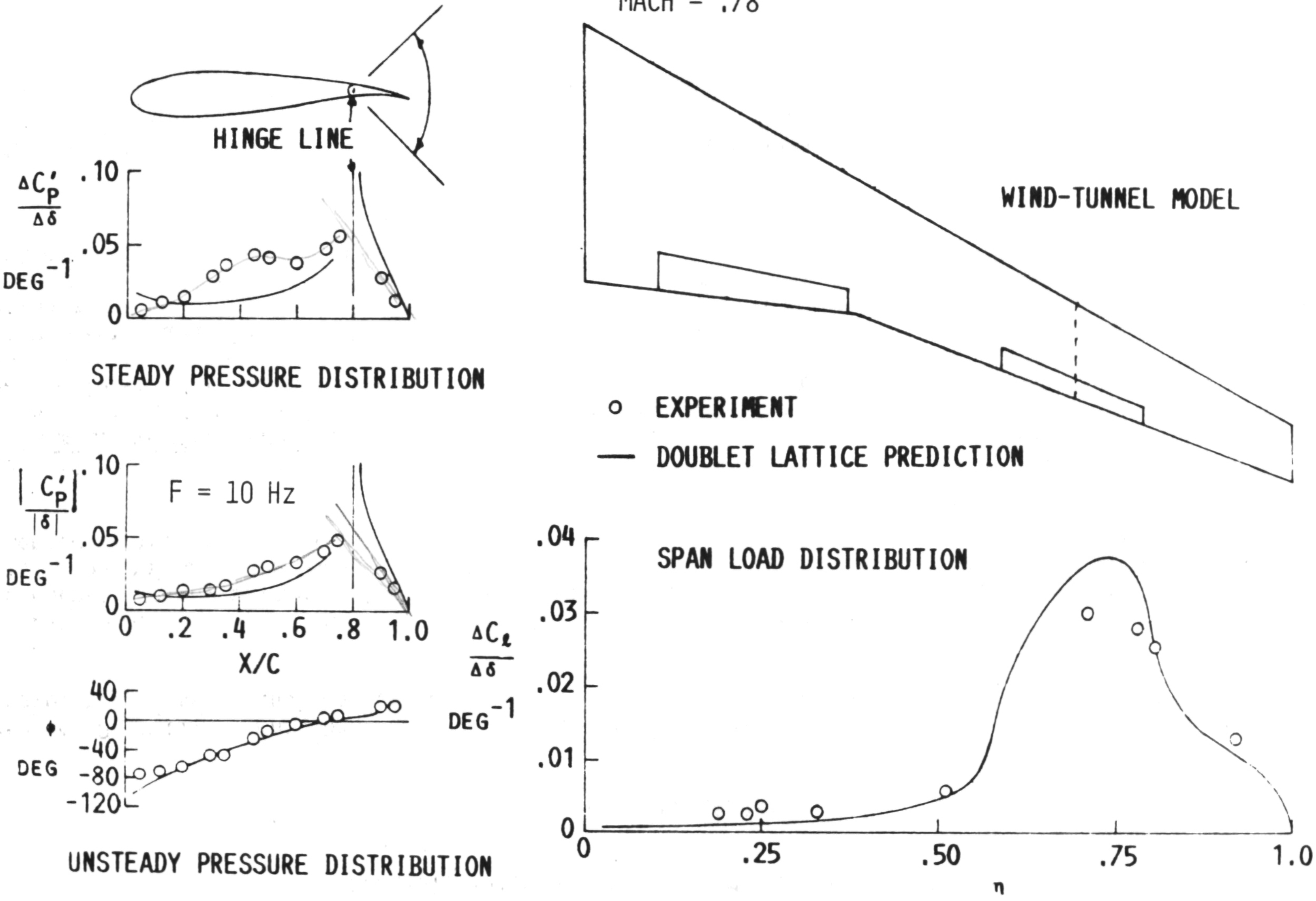
The general conclusion was that Doublet Lattice overpredicted the pressure amplitude especially aft of the control surface hinge line. However, Doublet Lattice gave good predictions of the pressure phase.

Future Plans - Plans are to develop techniques to derive empirical corrections, to apply to the Doublet Lattice calculations. Also, wind tunnel tests have recently been completed on the right semispan flight-test article of the ARW-2. Once comparisons of the aerodynamic wind tunnel data with analysis have been made, the corrections to the Doublet Lattice calculations for ARW-2 will be evaluated.

Figure 21(a).

COMPARISON OF EXPERIMENTAL CONTROL SURFACE UNSTEADY AERODYNAMICS WITH DOUBLET LATTICE PREDICTIONS

MACH = .78



- O OVERPREDICTION OF THE PRESSURE AMPLITUDE
- O GOOD PREDICTION OF THE PRESSURE PHASE

Figure 21(b).

ANALYTICAL TECHNIQUE DEMONSTRATES CONTROL OF SPACE STRUCTURE THERMAL DISTORTION BY APPLIED HEATING

Howard M. Adelman and Raphael T. Haftka
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Extension 3451

RTOP 506-53-53

Research Objective - The objective of the research is to develop analytical procedures to demonstrate the feasibility of using applied heating to control thermal distortions in orbiting spacecraft.

Approach - As a first step, the appropriate equations were developed and solutions obtained to determine the corrective temperatures at specified control points which offset distortions caused by orbital heating. The calculations were performed using closed-form solutions for free-free beams and were then extended to the general case of a finite-element-modeled structure and demonstrated for a space antenna.

Accomplishment Description - A set of matrix equations has been derived and solved to calculate the optimum corrective temperatures at a set of preassigned locations. The optimum temperatures are those which minimize the overall (rms) distortions of the structure from its ideal shape. The procedure has been implemented in the EAL/SPAR finite-element analysis program and demonstrated for the reflector of a 750 meter radiometer antenna. The antenna is in low-earth orbit and is distorted by a combination of solar, earth, and albedo heating. A thermal analysis was performed and a worst case temperature distribution selected. Twelve control points were located as shown in the figure. The original and corrected distortions are compared in terms of the normal deflections along a diagonal of the dish. The rms distortion of the dish was reduced by a factor of four and the maximum distortion was reduced by a factor of seven.

Future Plans - A study is underway to determine the effects of varying the locations and distributions of control points on the effectiveness of the corrections. A technique is being developed to automatically select the optimal locations of a given number of control points to correct a specified distortion.

Figure 22(a).

CONTROL OF ANTENNA THERMAL DISTORTION BY CORRECTIVE HEATING

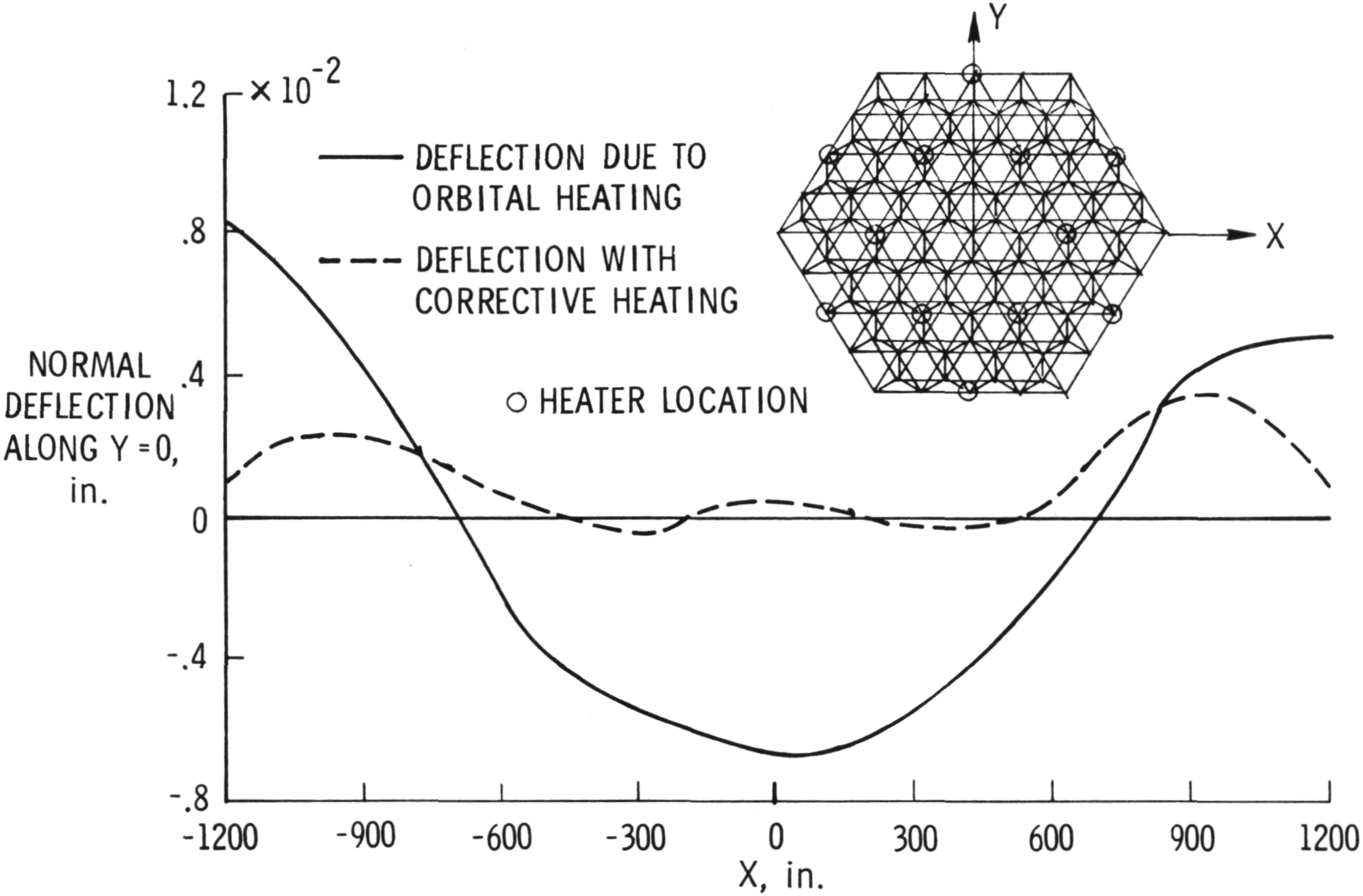


Figure 22(b).

APPLICATION OF REDUCED BASIS METHOD TO TRANSIENT THERMAL ANALYSIS

Charles P. Shore
Multidisciplinary Analysis and Optimization Branch
Extension 3834

RTOP 506-53-53

Research Objective - The large number of degrees of freedom required in the solution of structural problems resulting from geometry and structural arrangement considerations. This has led to methods to reduce the number of degrees of freedom and hence computer costs. One such method is the reduced basis technique which combines the classical Rayleigh-Ritz approximation with contemporary finite-element methods to retain modeling versatility as the degrees of freedom are reduced. The reduced basis technique has recently been implemented for nonlinear transient thermal analysis.

Approach - The effectiveness of the method depends upon representation of local temperatures by a few global modes or basis vectors, typically obtained from the solution of a linear thermal eigenvalue problem associated with the transient problem. These modes are then used as basis vectors to transform the full system of nonlinear equations into a reduced system of nonlinear equations with modal participation coefficients as the unknowns.

Accomplishment - The technique has been successfully applied to the two problems illustrated in the figure. The problem to the left represents a 58 in. segment of the lower surface of the Space Shuttle wing. A total of 16 selected thermal mode shapes from two thermal eigenvalue problems and a steady-state temperature distribution corresponding to time averaged values of the heat input were used as basis vectors in the reduction process. The resulting temperatures compared well with temperatures obtained from a SPAR Thermal Analyzer solution of the full system of 84 equations.

The problem to the right represents orbital heating on a large space antenna 2500 ft. diameter, graphite/epoxy composite, tetrahedral-truss associated with a microwave radiometer spacecraft. Although conduction effects for this problem were essentially negligible, the structure has sufficient thermal mass to require a transient rather than steady-state solution for accurate prediciton of temperatures within the structure. A set of six vectors based on steady-state temperature distributions from selected times in the orbital heat pulse were used in the reduction process and the results compared with results for the full system of 109 equations. The temperature histories agreed within 3°R over the entire orbit.

Future Plans - Since the success of the method obviously depends on the choice of basis vectors used to reduce the equations, efforts will continue to find techniques for selecting the type and minimum number of vectors for acceptable temperatures.

Figure 23(a).

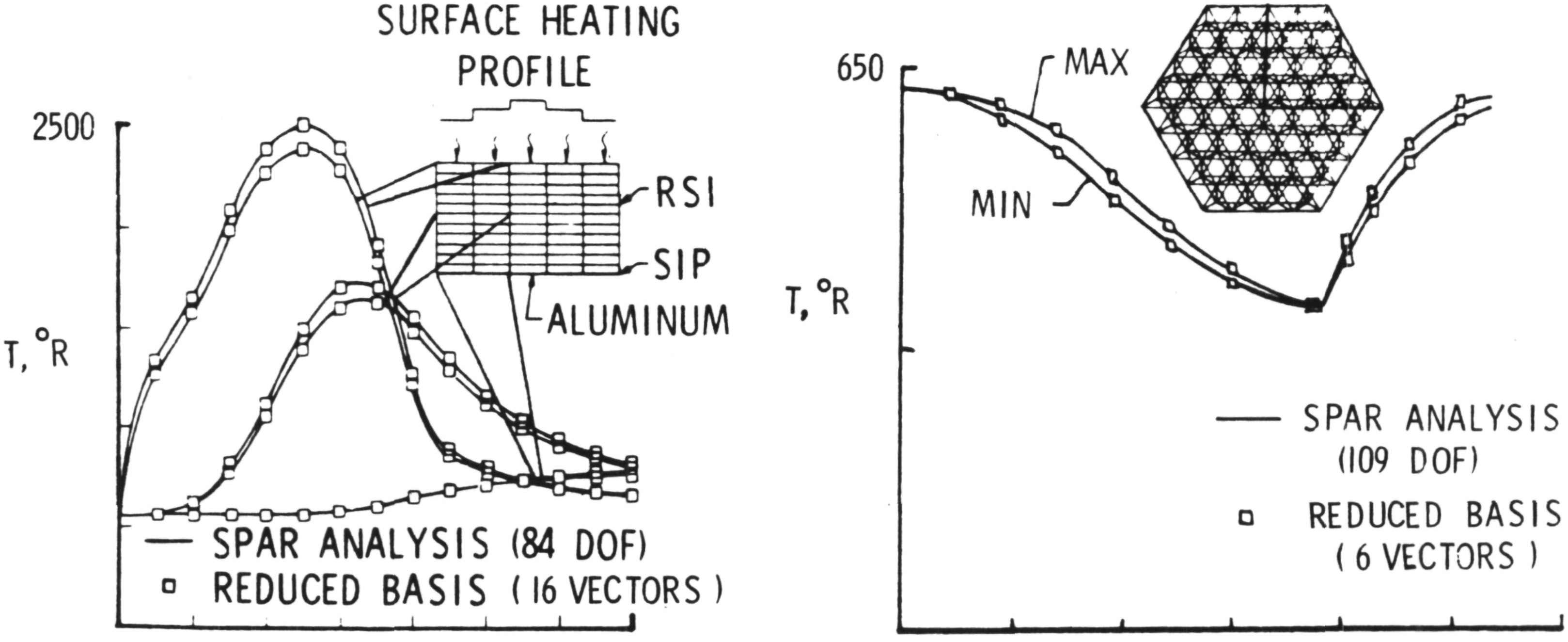
APPLICATION OF REDUCED BASIS METHOD TO TRANSIENT THERMAL ANALYSIS

$C\dot{T} + KT = Q$

$T = \Gamma\psi$

$\bar{C}\dot{\psi} + \bar{K}\psi = \bar{Q}$

- FAR FEWER UNKNOWNS IN ψ THAN IN T
- KEY TO METHOD - CHOICE OF Γ



SHUTTLE WING BAY

RADIOMETER ANTENNA DISH

Figure 23(b).

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SPAN-MAT: Spanwise Measurement of Atmospheric Turbulence

Robert K. Sleeper and Harold N. Murrow
Multidisciplinary Analysis and Optimization Branch
Extensions 2273 and 3527

RTOP 505-44-23

Research Objective - The gradient of air turbulence across the wing is known from experience to be capable of imposing severe roll disturbances on aircraft yet due to a lack of 2D statistical turbulence data it is not currently accounted for in piloted simulations and aircraft control and response analyses. The objective of this research is to determine realistic time histories and statistical properties of atmospheric turbulence in the spanwise direction at low altitudes pertinent to takeoff and landing operations to fill this void.

Approach - Atmospheric gust velocities are obtained at the nose and wing tips of a very stiff, instrumented aircraft (B-57B). Auto- and cross-spectral characteristics of components of these velocities are determined which respectively indicate the power distribution of the turbulence with frequency at, and mutually between, the wing tips. These characteristics then are compared with those derived based on a well-known theoretical atmospheric turbulence model.

Accomplishment Description - A B-57B sampling aircraft shown in the figure was equipped with an inertial platform, rate gyros, accelerometers, flow vanes, pitot tubes, and pressure and temperature sensors to measure gust velocities. An example of a vertical gust velocity time history excerpted from a flight record measured near a thunderstorm while participating in the 1982 Joint Airport Weather Studies (JAWS) is shown. For such atomospheric turbulence assumed to be continuous, homogeneous and isotropic, von Karman derived a mathematical model with an autopower-spectral-density (APSD) distribution per unit variance which for the measured variance of the turbulence record is shown as a function of reduced frequency (the ratio of the turbulence frequency to airspeed) by dashed lines for both wing tips on the left side of the lower figure (the vertical scale for the right wing is shifted for clarity). The area under the curve is the variance of the record level and the nature of the turbulence is characterized by the integral scale factor L, a characteristic length which can be identified from determining the frequency below which the power is essentially constant and above which it rolls off at a rate of 5

Figure 24(a).

SPAN-MAT: Spanwise Measurement of Atmospheric Turbulence

Continued

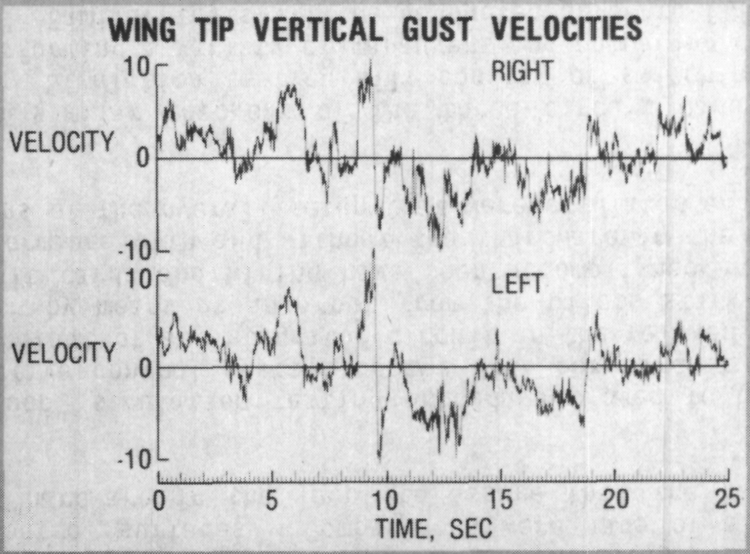
decades for 3 decades of frequency change. Superimposed on the model APSD descriptions are preliminary APSD estimates from the measured wing tip vertical gust velocities where the variance is computed directly from the gust velocity measurement and the characteristic length, or L value, of the model APSD is selected to match the measured APSD. A von Karman cross-power-spectral density (CPSD) function has been analytically derived by J. C. Houbolt in NASA CR-2011 for a 2-dimensional, momentarily frozen gust field; both model CPSD and APSD curves are shown dashed on the right side of the lower figure for the given sampling aircraft span, the measured variance and the L value determined from matching the estimated and model APSD curves. The CPSD estimates lie between the model APSD (where the atmosphere conceptually imparts no roll disturbance) and CPSD curves, approaching the APSD curve at high frequencies. These preliminary data suggest that roll disturbances due to high frequency turbulence components are less than expected (perhaps none at very high frequencies), however, the CPSD estimates identify frequencies where aircraft are susceptible to relatively large roll disturbances. Additional data have been obtained and are being processed to satisfy the stated research objectives. Correlations with meteorological parameters and remote sensing via doppler radars are being conducted by the NASA Marshall Space Flight Center.

Future Plans - Examination of the storms data continues. Improved dynamic pressure sensors developed at Langley by the Flight Electronics Division have been installed. The aircraft will then be used to search for continuous, long duration turbulence encounters, participate in other storms project, and in addition, conduct tests to compare in-flight with fixed tower gust velocity measurements.

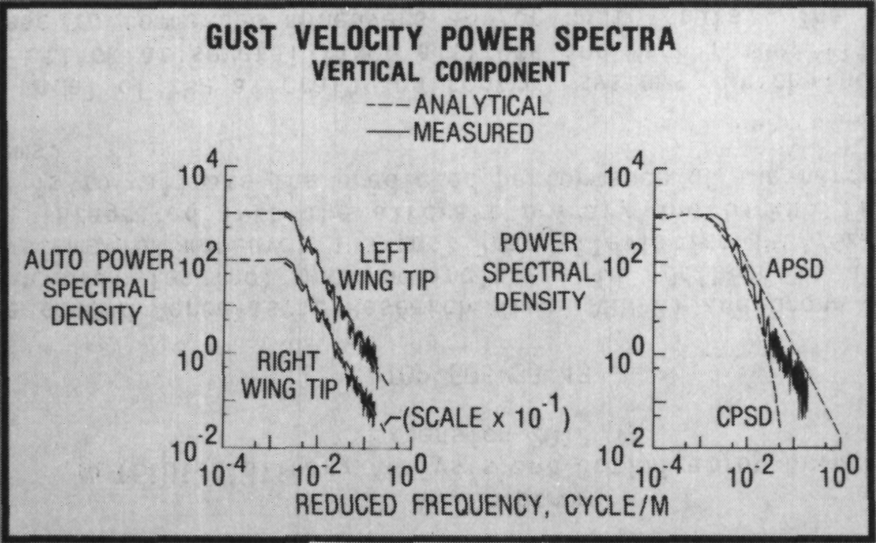
Figure 24(b).

SPAN-MAT: SPANWISE MEASUREMENT OF AIR TURBULENCE

SAMPLING AIRCRAFT



WING TIP VERTICAL GUST VELOCITIES



GUST VELOCITY POWER SPECTRA

VERTICAL COMPONENT

Figure 24(c).

DAST ARW-2 "HARDWARE IN THE LOOP" SIMULATION TESTING

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Extension 2012

RTOP 505-33-43

Research Objective - The second Aeroelastic Research Wing (ARW-2) and drone aircraft of the DAST (Drones for Aerodynamic and Structural Testing) program includes, in addition to a flutter suppression system (FSS), active control systems for maneuver and gust load alleviation (MLA/GLA) and relaxed static stability (RSS) that must be integrated into the aircraft primary and backup flight control systems. The purpose of this research is to validate the predicted performance of the hardware fabricated to implement the active control systems.

Approach - A simulation model of the aircraft and control systems, which included nonlinear aerodynamic effects due to angle of attack at several fixed altitute and Mach number flight conditions, was used to evaluate aircraft response to commanded maneuvers and/or gust inputs. The overall simulation was conducted both with the active control system simulated and with flight hardware in the simulation loop. The flight hardware consisted of the Drone Active Control Electronics (DACE) box and the wing left semi-span with associated servovalves, actuators, and control surfaces. Comparisons were made of aircraft response to commanded inputs with and without the "hardware in the loop" to assure that the hardware performed as expected.

Accomplishment Description - The "hardware-in-the-loop" simulation testing procedure proved to be very useful in checking out the implementation of the active control systems on the DACE box circuit cards. The simulation also defined the need to offset the output of an integrator circuit in the relaxed static stability control system at the time of drone launch by means of an input from the pilots stick. The required corrections and modifications to the circuit cards and wiring have been accomplished and comparisons of simulation results now show similar performance with and without the "hardware in the loop." The attached figure describes pictorially the portions of the overall setup that were simulated and those that included actual hardware.

Future Plans - Plans have been formulated to do a similar checkout of the three circuit cards that implement the onboard backup flight control system. Simulation testing will consist of switching from the primary to backup flight control system while performing a variety of maneuvers and comparing results obtained with and without the "hardware in the loop." Similar tests will be conducted prior to flight at DFRF including the portion of the control system that will be implemented on the ground computer.

Figure 25(a).

CONTROL SYSTEM AND AIRCRAFT SIMULATION INTEGRATION WITH FLIGHT HARDWARE FOR DAST ARW-2

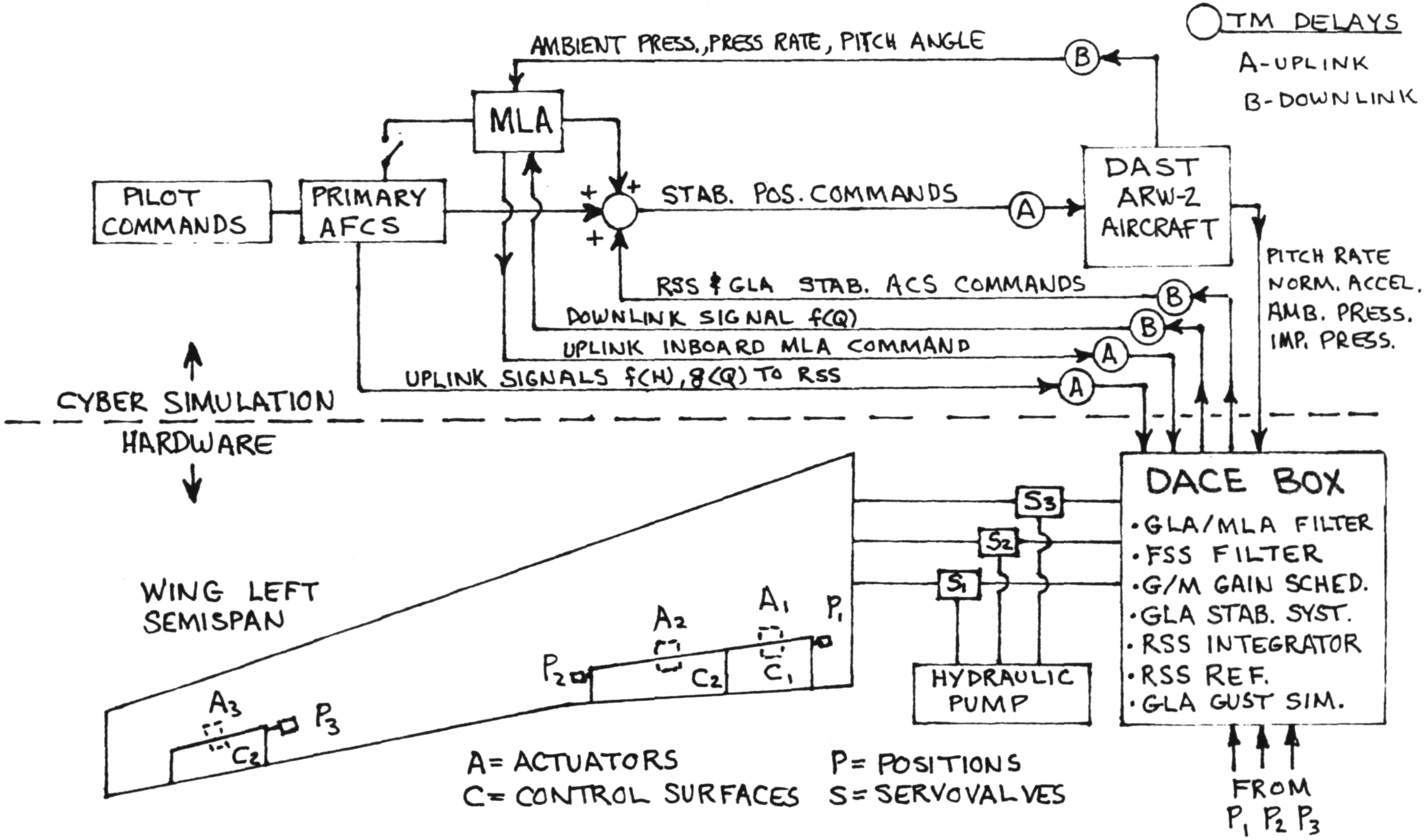

Figure 25(b).

STRUCTURAL OPTIMIZATION EXECUTED ON CRAY-1 TEN TIMES FASTER THAN ON CYBER-173

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RTOP 505-33-53

Research Objective - The objective of this research was to evaluate the benefits of supercomputers for applications to structural optimization.

Approach - Transmit a file containing the Engineering Analysis Language (EAL) version of the Programming System for Structural Synthesis (PROSSS) from an LaRC VAX minicomputer to an Ames Research Center VAX minicomputer. Install EAL/PROSSS on the CRAY-1 at Ames and test the cost effectiveness of executing structural optimization on the CRAY-1 as opposed to the LaRC CYBER computers.

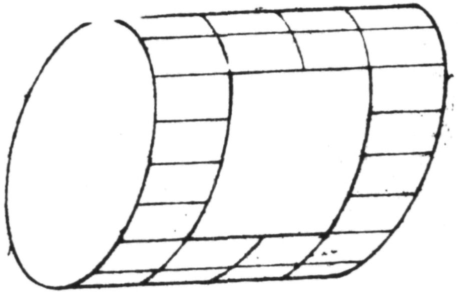
Accomplishment Description - When installing EAL on the CRAY-1, advantage of the vectorization capability of the CRAY-1 was taken in a few isolated places, such as factoring and inner products. Previous studies of supercomputers for structural analysis at LaRC using the CYBER 201 showed little benefit. A one-way communications line was established for ARC to retrieve the EAL/PROSSS file. After the file was transmitted, EAL/PROSSS was installed on the CRAY-1 with only slight modifications to the code. Testing of EAL/PROSSS on the CRAY-1 was done with the finite-element model of a 352 DOF idealized segment of a fuselage with a cutout. The cross-sectional areas of rods and beams, and the thicknesses of membranes were used as design variables in a nonlinear programing method with gradients computed inside the optimizer by finite difference. Results from the CRAY-1 were identical to those found using the CYBER 173 at LaRC. Where the problem took 559 CPU seconds to complete on the CYBER 173, it only required 55 CPU seconds on the CRAY-1.

Future Plans - A tape has been received from ARC that should allow two-way communication between Ames and LaRC. When that is established, more extensive testing of EAL/PROSSS can be done on the CRAY-1. If structural optimization using EAL/PROSSS on the CRAY-1 proves to be cost effective, computer time on the ARC CRAY-1 is planned to test our optimization techniques on large, costly, finite-element models.

Figure 26(a).

SUPERCOMPUTER -- CRAY 1
IMPROVES SPEED OF STRUCTURAL OPTIMIZATION BY A FACTOR OF 10

OBJECT OF OPTIMIZATION

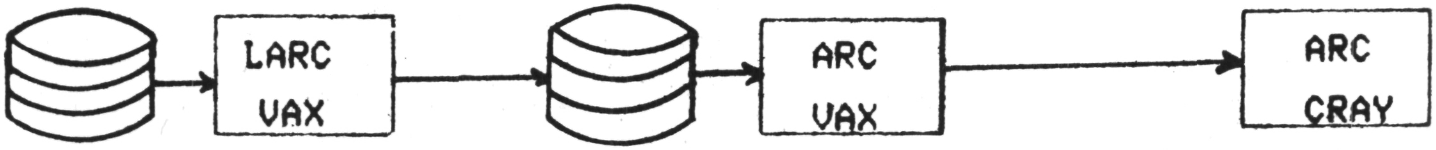


352 DOF
58 RODS
76 BEAMS
56 MEMBRANES

COMPUTER CODE

EAL VERSION OF THE PROGRAMMING SYSTEM FOR STRUCTURAL SYNTHESIS (PROSSS) WHICH WAS ORIGINALLY DEVELOPED AT LARC ON CYBER COMPUTERS.

LARC - AMES COMPUTER LINKUP



RESULT

CRAY 1 55 CPU SECONDS CYBER 173 559 CPU SECONDS

Figure 26(b).

NEW GROUND BROKEN IN STRUCTURAL DYNAMICS OPTIMIZATION

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RTOP 505-33-53

Research Objective - The objective of this program is to develop fundamental optimization theory that would improve computational efficiency of structural optimization and extend it to those categories of problems whose optimum solutions can not be obtained under the state of the art.

Approach - One of the problems that under the state-of-the-art lacked a general and effective solution procedure was optimization of a structure under forced response due to oscillatory loads. The difficulty stems from the resonance phenomenon which introduces a response singularity thus partitioning the design space into disjoint subspaces. This is illustrated on the chart (top and two leftmost insets below) by an example of a shaft loaded by an oscillatory torque. Disjointness of the subspaces and nonconvexity of their boundaries prevented existing algorithms from finding optimum solutions in the entire design space. Although in this elementary case the disjointness could be overcome by simply optimizing separately in the two subspaces, the more complex cases encountered in most practical applications have many eigen-frequencies, hence, the number of subspaces is too large to optimize in each of them.

Accomplishment Description - A new algorithm has been developed and shown effective in dynamic optimization as illustrated in the chart. First, a continuous optimization problem is solved within confines of a subspace of the frequency domain bordered by the natural frequency values (chart, omega 1 - omega 2 plot) transforming the shaft from design A to B reducing its mass in about 12 iterations (chart, curve and inset at lower right). Next, a potential for a design at lower mass is evaluated for each neighboring frequency subspace using inexpensive linearized expressions, and the search shifts to the subspace of greatest potential where a continuous optimization is repeated, and so on. The chart shows the process moving from subspace no. 1 to subspace no. 2 where improvement from C to D is made, and staying in subspace 2 for a final refinement from E to F. Taking as a reference the minimum mass obtainable in the initial frequency subspace, computational experience to date indicates that the new procedure yields additional mass reductions of up to 84 percent of the reference mass.

Future Plans - Application to problems of current interest such as large space structures and rotorcraft which are dominated by dynamic loads.

Figure 27(a).

NEW GROUND BROKEN IN STRUCTURAL DYNAMICS OPTIMIZATION

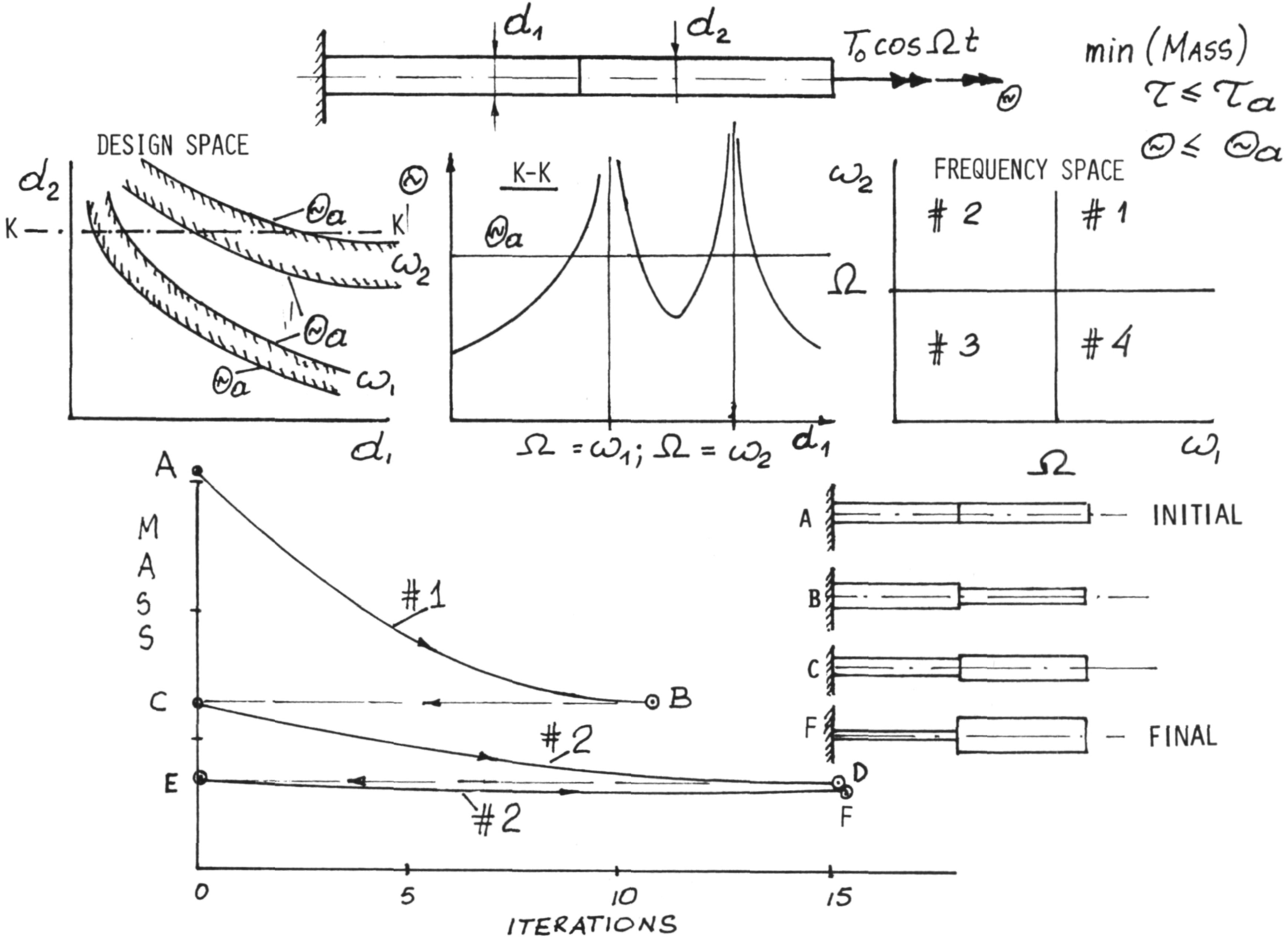
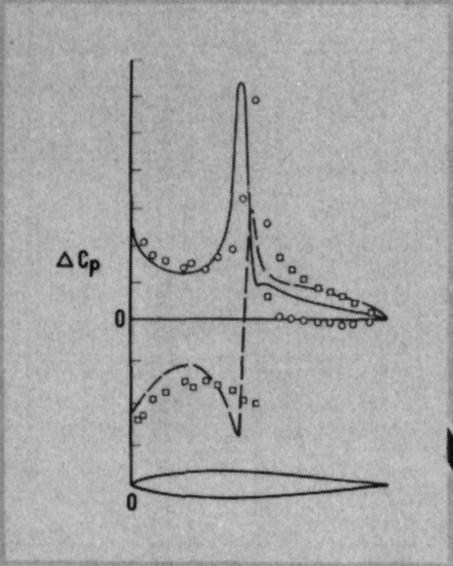
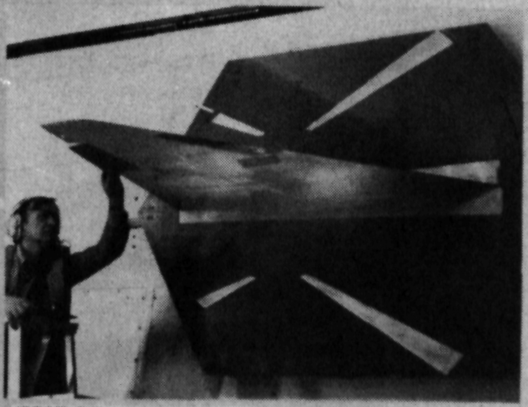


Figure 27(b).

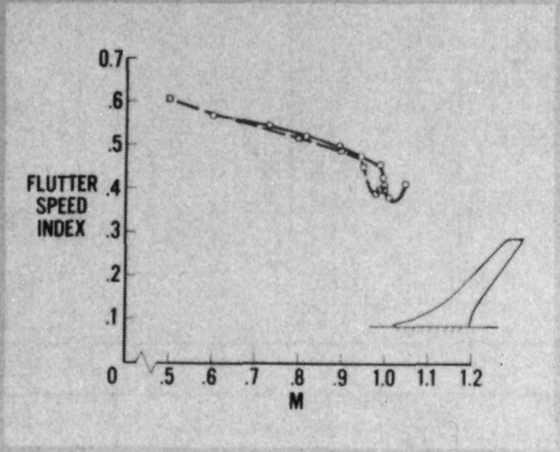
UNSTEADY AERODYNAMICS



THEORETICAL AERODYNAMICS



EXPERIMENTAL AERODYNAMICS



AEROELASTIC ANALYSIS

Figure 28.

NASA
LCh-81-36

UNSTEADY AERODYNAMICS
5-YEAR PLAN

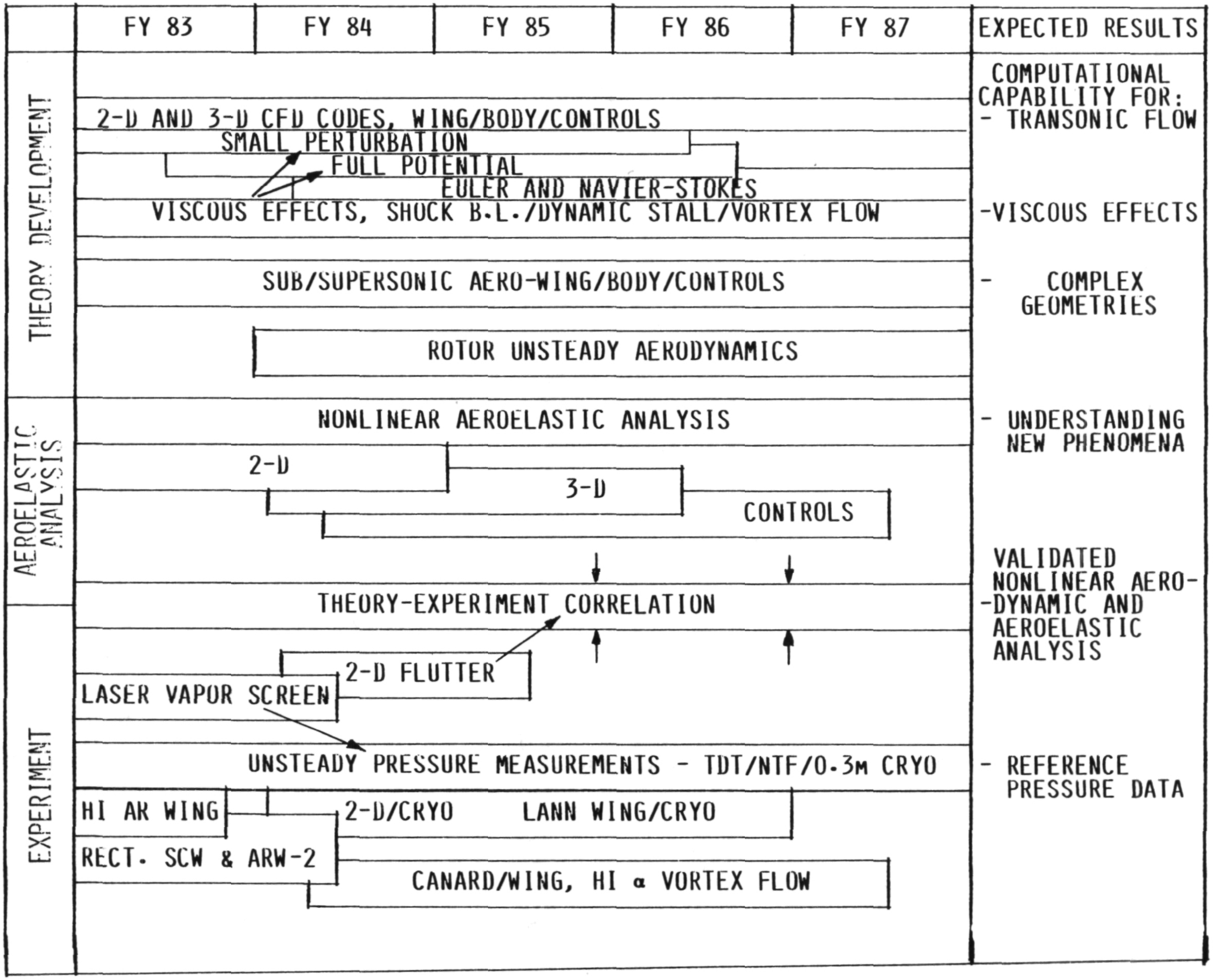


Figure 29.

NEW DIFFERENCING SCHEME FOR TRANSONIC CALCULATIONS ELIMINATES ENTROPY-VIOLATING EXPANSION SHOCKS

Woodrow Whitlow, Jr.
Unsteady Aerodynamics Branch
Extension 4236

and

Mohamed M. Hafez
Computer Dynamics, Inc.
Extension 2627

RTOP 505-33-43

Research Objective - Currently, theoretical transonic unsteady aerodynamic loads are obtained primarily by solving the transonic small disturbance (TSD) equation. However, TSD theory fails in the region of blunt leading edges and is applicable only to thin bodies at small angles-of-attack undergoing small amplitude motions. Since a full potential formulation is more general than TSD theory, the objective of this research is to develop a finite difference method for solving the unsteady full potential equation.

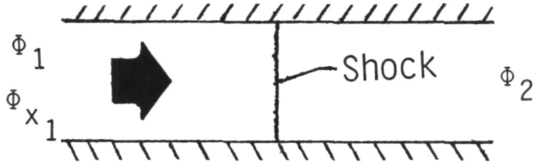
Approach - Classical differencing schemes, such as Murman's, have properties such that flows that contain nonphysical, entropy-violating expansion shocks may be calculated. In the present effort, the spatial terms of the full potential equation are discretized using a differencing scheme that does not admit solutions with expansion shocks. This technique is based on differencing the mass flux function in the potential equation.

Accomplishment Description - The new method was tested on the steady, one-dimensional equation for the following problems: (1) Subsonic, (2) Supersonic, (3) Transonic with compression shock, and (4) Sonic with expansion shock as input. The nature of the flow is determined by the boundary conditions on the potential, Φ, and its derivative, Φ_x. When the proper combinations of Φ and Φ_x are specified at the boundaries the present method converges to the correct physical flow independent of the starting solution. Fast convergence was obtained for all cases. Since problems 3 and 4 are the more interesting cases, these results are shown in the accompanying figure. The sketch on the left of the figure shows that for transonic flows with compression shocks, the new method converges to solutions with sharply defined shocks that are very near the exact value. The important point illustrated on the right of the figure is that flows with entropy-violating expansion shocks are not admitted as solutions. As shown in the figure, when such shocks are input as the initial condition, they are eliminated, and the solution converges to the correct sonic flow.

Current Efforts and Future Plans - The mass flux differencing technique is currently being applied to the steady, two-dimensional full potential equation. Future plans include extending the method to unsteady, two-dimensional flows.

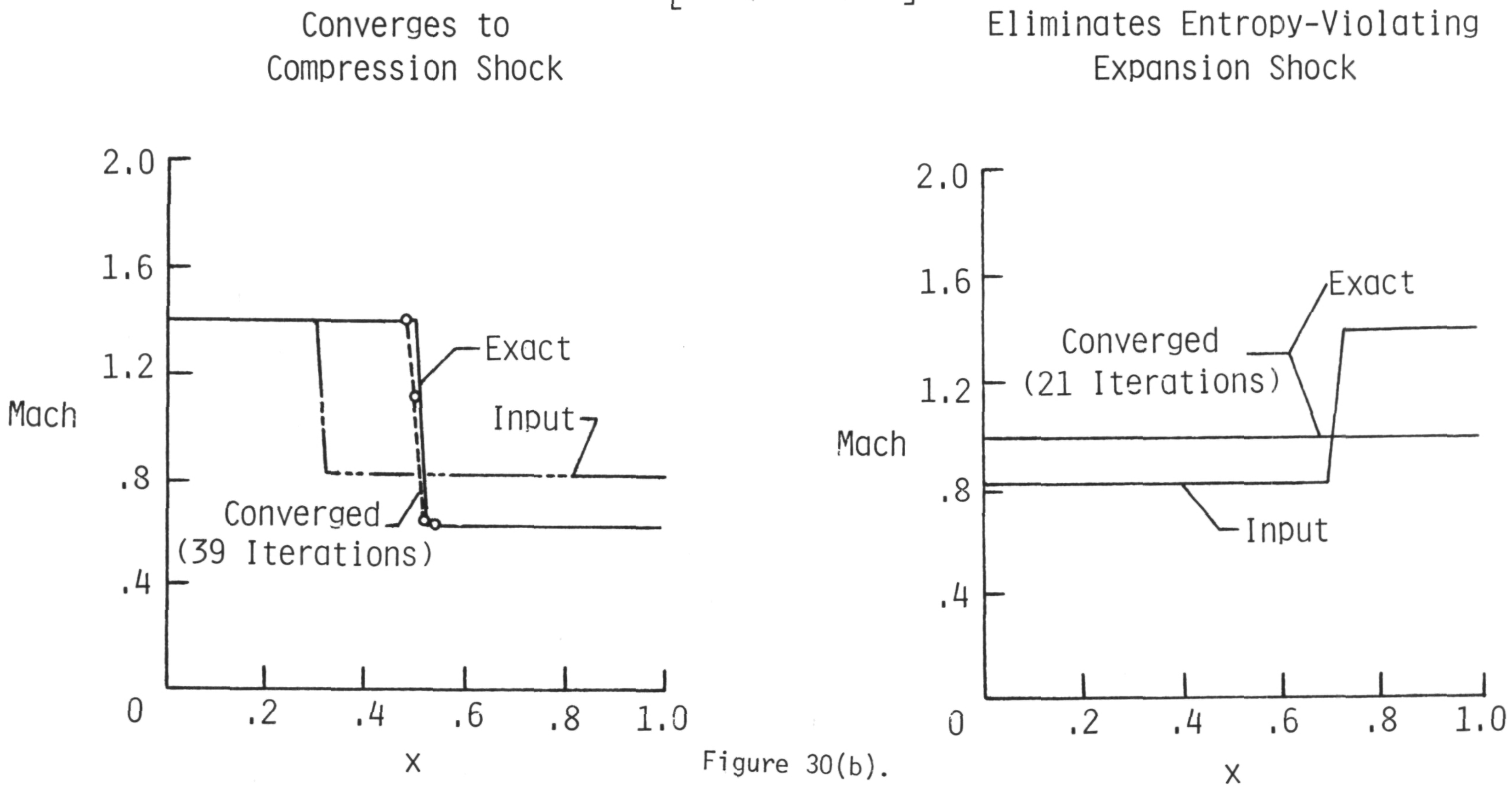
Figure 30(a).

NEW DIFFERENCING SCHEME FOR TRANSONIC CALCULATIONS ELIMINATES ENTROPY-VIOLATING EXPANSION SHOCKS



$$(\rho\Phi_x)_x = 0$$

$$\rho = \left[1 - \left(\frac{\gamma - 1}{\gamma + 1}\right)\Phi_x^2\right]^{\frac{1}{\gamma - 1}}$$


Converges to Compression Shock

Eliminates Entropy-Violating Expansion Shock

Figure 30(b).

IMPROVED MODELING INCREASES ACCURACY OF UNSTEADY TRANSONIC CALCULATIONS

Robert M. Bennett, David A. Seidel, and Woodrow Whitlow, Jr.
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Extension 4236

RTOP 505-33-53

Research Objective - The objective of this research is to improve the accuracy and utility of finite difference computer programs for unsteady transonic aerodynamic calculations and flutter analysis.

Approach - Several important modifications and additions have been implemented in a transonic finite-difference computer code. Included are an additional unsteady term in the differential equation, a new treatment of the far field boundary conditions, improvement of the transonic algorithm, and development of an improved distribution of points of the finite difference grid.

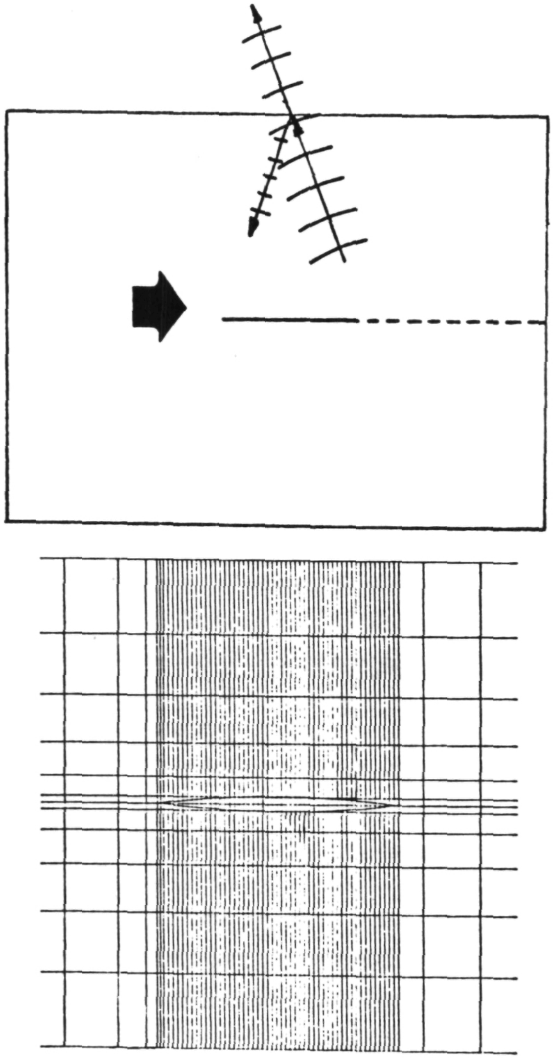
Accomplishment Description - The program LTRAN2-NLR was limited to low reduced frequencies and sensitive to flow conditions. The $\phi\upsilon\upsilon$ term in the complete differential equation was added to the code, allowing accurate calculations for all frequencies. A monotone differencing scheme in the transonic algorithm was incorporated which considerably extended the Mach number and angle of attack range of the program. Nonreflecting boundary conditions were added which allowed a reduction of the extent of the grid and thus reduced computer costs. In addition a new finite difference grid was developed that considerably enhanced the accuracy of the results by eliminating spurious oscillations in the unsteady loads. The program with these modeling improvements is called XTRAN2L. A key factor in developing and assessing the improvements was the implementation of a pulse-transfer function technique based on fast Fourier transforms to obtain unsteady airload frequency response functions from a single transient calculation. This provides airloads for all frequencies of interest with a significant computational savings. Comparisons with exact linear theory results for a flat plate airfoil permits rapid assessment of accuracy of the parameters, such as the grid, being investigated. The figure gives a sketch of the influence of the grid and nonreflecting boundary conditions. The improved code XTRAN2L is more robust, more accurate, and reduces the computer costs by 33%.

Future Plans - These techniques and improvements will be implemented in the 3-D transonic code XTRAN3S and in a full potential code that is under development. The improvements demonstrated in the 2-D calculations are of great significance for 3-D aeroelastic analysis capability since they enable practical transonic flutter analysis.

Figure 31(a).

IMPROVED MODELING INCREASES ACCURACY OF UNSTEADY TRANSONIC CALCULATIONS

- MODIFIED GRID
- NONREFLECTING BOUNDARY CONDITIONS
- MORE ACCURATE
- 33% SAVINGS IN COMPUTER COSTS



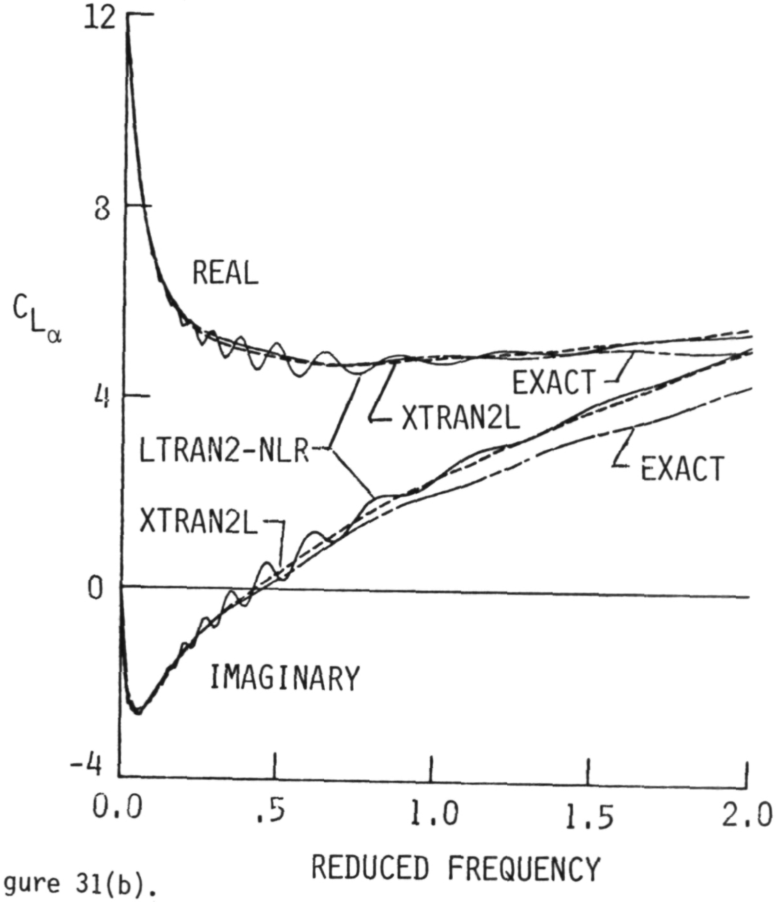


Figure 31(b).

UNSTEADY SURFACE PRESSURES ON CLIPPED DELTA WING OBTAINED FROM PANEL METHOD AND EXPERIMENT

E. Carson Yates, Jr., Herbert J. Cunningham, Robert N. Desmarais, Robert W. Hess
Extension 4236

RTOP 505-33-53

Research Objective - The objective of this effort is to develop a general aerodynamic panel-method computer program and to validate it by applying it to several wings and comparing the results with experimental data and with other calculations.

Approach - Application of a generalized Green's function method to the full, time-dependent potential-flow equation leads to an integral equation for the velocity potential at any point in the flow, including points on the surface of a body in the flow. The SOUSSA (Steady, Oscillatory, and Unsteady Subsonic and Supersonic Aerodynamics) P1.1 program is a panel-method code which implements this integral equation for linearized subsonic flow in the complex-frequency domain, and is applicable to general shapes such as complete aircraft having arbitrary shapes, motions, and deformations. Efficient computations are possible for multiple frequencies and multiple sets of vibration or deformation modes because the aerodynamic integrals are independent of both mode shapes and frequency and because the elements of the influence matrix depend on frequency in a very simple way.

Accomplishment Description - The SOUSSA panel method was not formulated primarily for application to isolated wings of simple shape, nor was it intended to be a competitor of lifting-surface theory. However, for validation of the P1.1 program pressure distributions and flutter characteristics have been calculated for such simple shapes so that comparisons can be made with both steady and unsteady lifting-surface calculations as well as with existing experimental data. Some results of one such application are shown in the accompanying figure. The wing, which was tested in the Langley Transonic Dynamics Tunnel, is a sharp-edge clipped delta oscillating in pitch. Mach number is 0.4, and reduced frequency based on root semichord is 0.66. The surface-paneling array used in the SOUSSA calculations contained 10 panels per chord and 10 panels per semispan on upper and lower surfaces. Calculated and measured surface pressures are compared in the figure at the 0.33 semispan station, and the overall good agreement shown is typical for other span stations and other freqencies.

Future Plans - Current activities include formulation of higher-order panels for both subsonic and supersonic speeds, improved implementaiton of the trailing-edge flow condition, and changes in program organization. These modifications should improve applicability and accuracy and reduce the cost of computation by nearly an order of magnitude.

Figure 32(a).

UNSTEADY SURFACE PRESSURES ON CLIPPED DELTA WING OBTAINED FROM PANEL METHOD AND EXPERIMENT

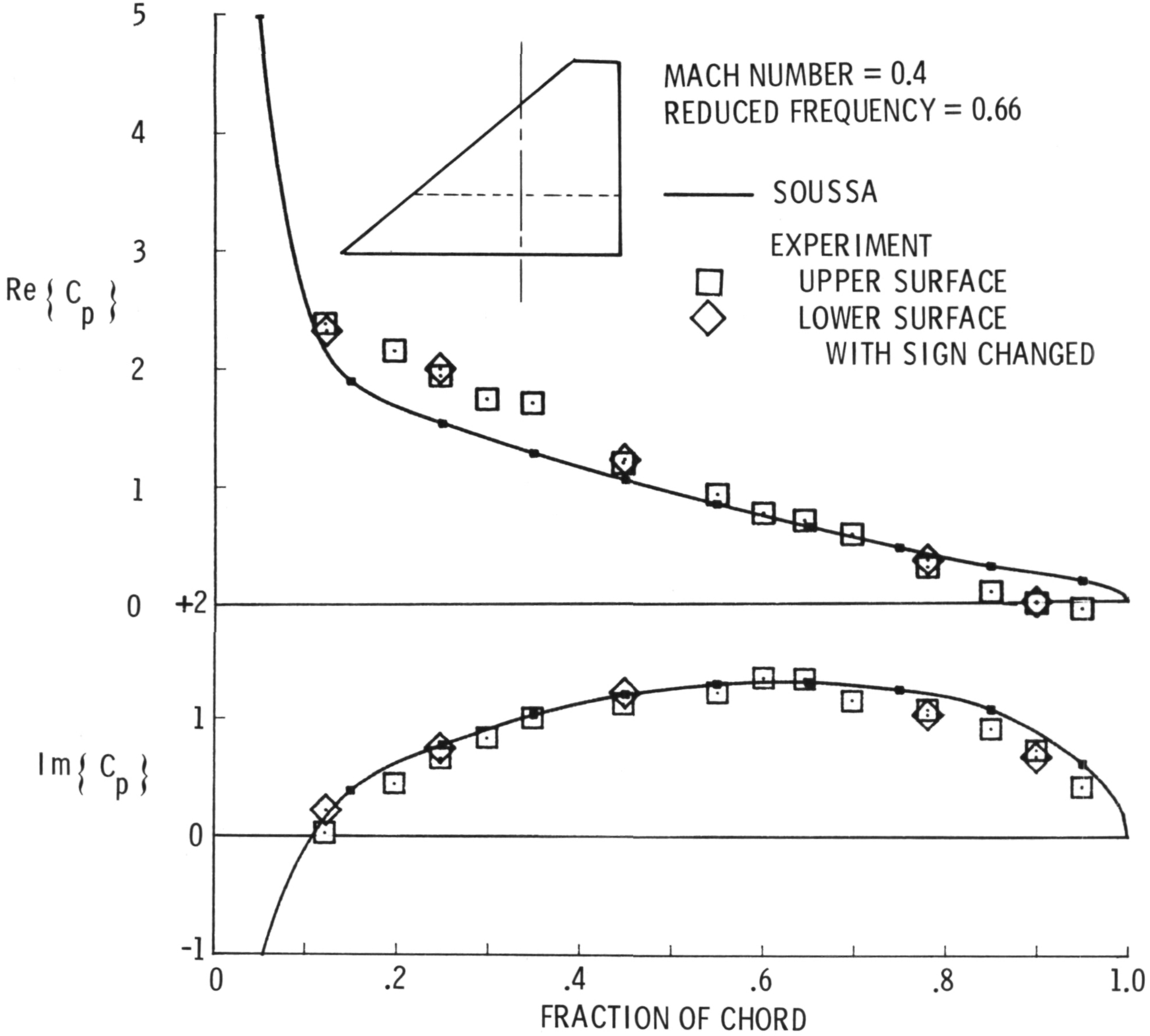


Figure 32(b).

VELOCITY POTENTIAL SMOOTHING TECHNIQUE ACCELERATES CONVERGENCE OF TRANSONIC CALCULATIONS

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Extension 4236

and

Mohamed M. Hafez
Computer Dynamics, Inc.
Extension 2627

RTOP 505-33-43

Research Objective - To maintain stability, classical finite difference methods for transonic calculations restrict the movement of shock waves to no more than one grid point per iteration. This is usually accomplished by adding an explicit damping term to the governing equation. Convergence rates of computed solutions are limited by the speed with which shock waves move to their final positions. A method which permits shocks to move more than one point per iteration should significantly increase convergence rates. The objective of this effort is to increase the efficiency of transonic computations by developing a method that allows shock movement of many grid points per iteration.

Approach - The full potential equation is discretized using a monotone method which is based on differencing the mass flux function. No damping term is added to stabilize the calculations. After each iteration, the slope of the velocity potential is checked for regions with unphysical behavior in the velocity gradients. In those regions, the potential is smoothed, giving a physically plausible velocity distribution over the entire flow field. This accelerates convergence of the calculations by permitting shock waves to move many grid points per iteration.

Accomplishment Description - The smoothing technique was tested for steady, one-dimensional transonic flow with an embedded compression shock. Calculations were made on an equally spaced grid with 50 points between x=0 and x=1. The sketch at the top right of the figure shows an example of an intermediate velocity potential distribution with an unphysical change in slope at x = 0.25 and of the resulting smoothed potential. The intermediate potential distribution would cause immediate failure of finite difference methods. The sketch at the bottom left shows that using the smoothing technique, the shock moved as many as 13 grid points per iteration. This allowed the shock to rapidly converge to its final position and thus accelerate convergence. The converged numerical solution shows good agreement with the exact solution. A comparison of iterations required by the present method and a method with no smoothing (damping required) is shown at the bottom right. Smoothing the solution increased the convergence rate for this case by more than a factor of six.

Current Efforts and Future Plans - The mass flux differencing technique is currently being applied to the steady, two-dimensional full potential equation.Future plans include developing an unsteady two-dimensional method and determining the feasibility of using the smoothing technique to increase the efficiency of two-dimensional steady and unsteady calculations.

Figure 33(a).

VELOCITY POTENTIAL SMOOTHING TECHNIQUE ACCELERATES CONVERGENCE OF TRANSONIC CALCULATIONS

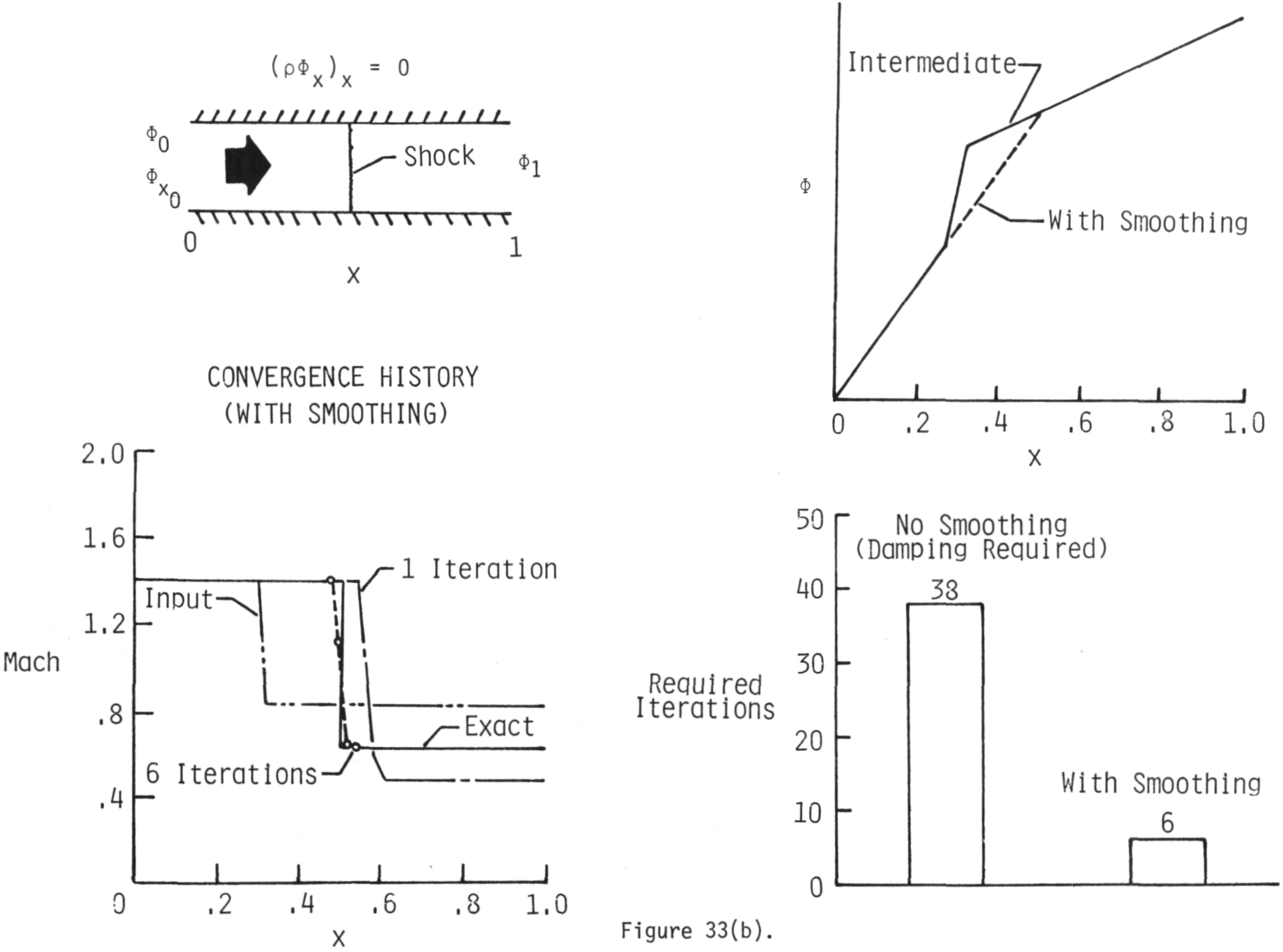

Figure 33(b).

LIFTING SURFACE THEORY APPLIED TO A HELICOPTER ROTOR IN FORWARD FLIGHT

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Extension 4236

RTOP 505-33-43

Research Objective - To develop an unsteady, compressible, lifting surface theory for a helicopter rotor in forward flight.

Approach - The approach is based on the acceleration potential formulation, resulting in an integral equation which relates the known downwash to the unknown loading. Using the vortex lattice approximation, a collocation method is used to solve for the unknown loads. This procedure is in contrast to the usual method which utilizes two-dimensional air forces, modified by assumed in flow velocities and wakes. In the present method, no assumptions have to be made regarding in flow velocities, and the time-dependent wake is properly taken into account so that "flutter" type air forces are directly obtained.

Accomplishment - The method has been programmed for the incompressible case and results have been obtained for swept tips, single and double blades, and for a rotor vibrating in a pitching mode at 4/rev. The accompanying figure illustrates the results obtained for a blade oscillating in a pitching mode about the 1/4 chord. The steady case is shown by the dashed line, the oscillating case illustrated by the solid line. The insert contains the amplitude of the harmonic content. The main effect of the oscillation is to increase the magnitude of the 4th harmonic.

Plans - To extend the method to the compressible case. This involved the derivation of the kernel for the compressible case, which is now underway. Once the compressible case is operational, it is a relatively easy job to set the program up to compute the noise generated by the blades at some field point, whether the observation point is moving with the aircraft or fixed on the ground. Subsequently, airfoil thickness effects will be added.

Figure 34(a).

LIFTING SURFACE THEORY APPLIED TO A HELICOPTER ROTOR IN FORWARD FLIGHT

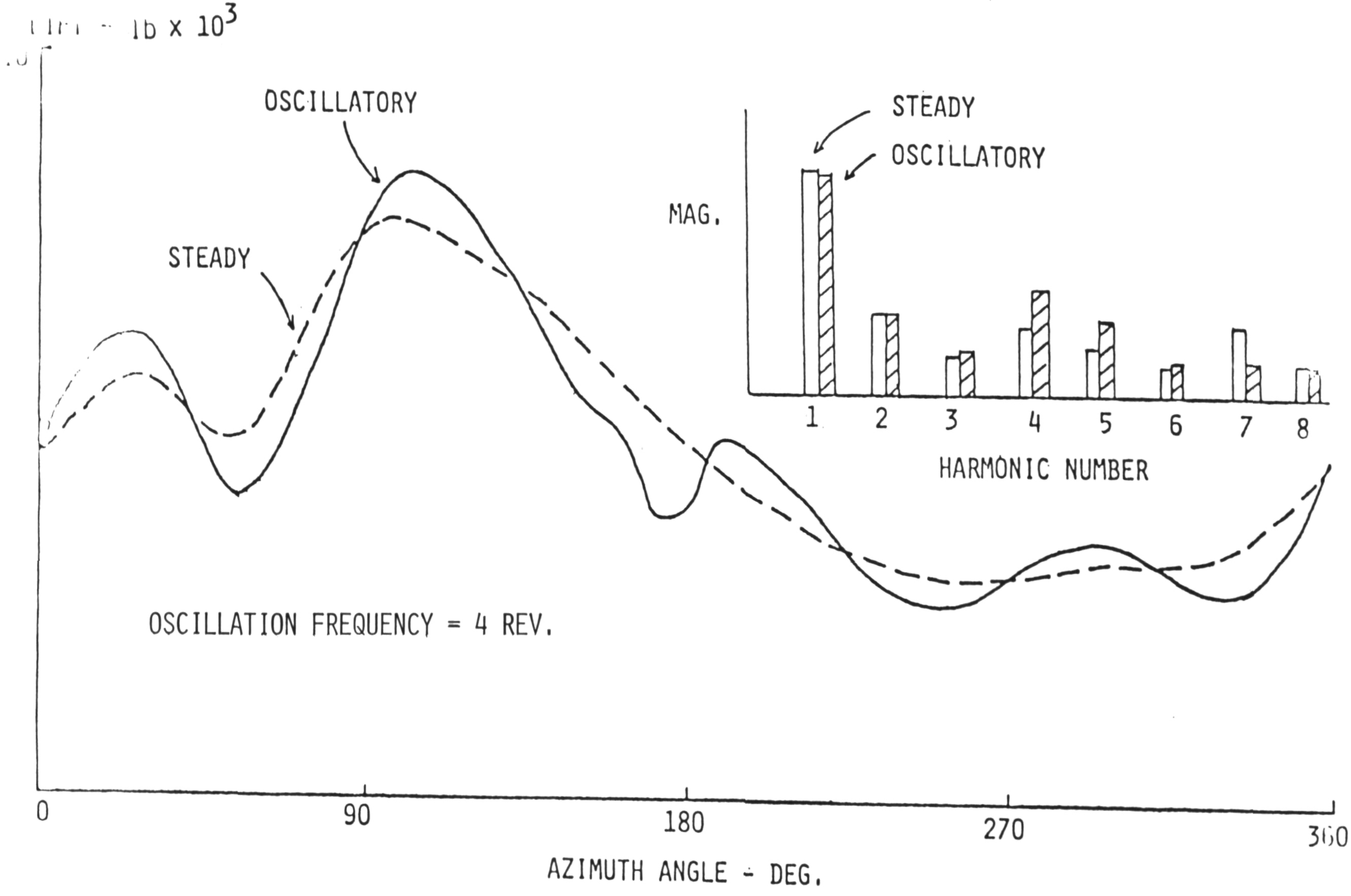

Figure 34(b).

ASSESSMENT OF 2-D AIRFOIL TRANSONIC FLUTTER CHARACTERISTICS

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Extension 4236

RTOP 505-33-43

Research Objective - The objective was to study the differences in the transonic flutter behavior of a conventional and a supercritical airfoil using a nonlinear, finite-difference, unsteady aerodynamic code.

Approach - The two-dimensional, finite-difference code XTRAN2L was used to calculate the aerodynamic forces for a prescribed airfoil pitch or plunge transient motion. These nonlinear, time-dependent forces were used to compute the harmonic forces by a linear Fourier transform technique. These harmonic forces were then approximated by a rational function (Pade approximants) to obtain forces for use in root locus flutter analysis. This technique requires only one run of the expensive aerodynamic code for each mode of airfoil vibration to obtain an adequate representation of the forces for use in the flutter analysis for any frequencies and variations in the structural parameters of interest. The accuracy of these linear techniques was verified by direct calculation of the coupled structural and aerodynamic equations with the nonlinear code.

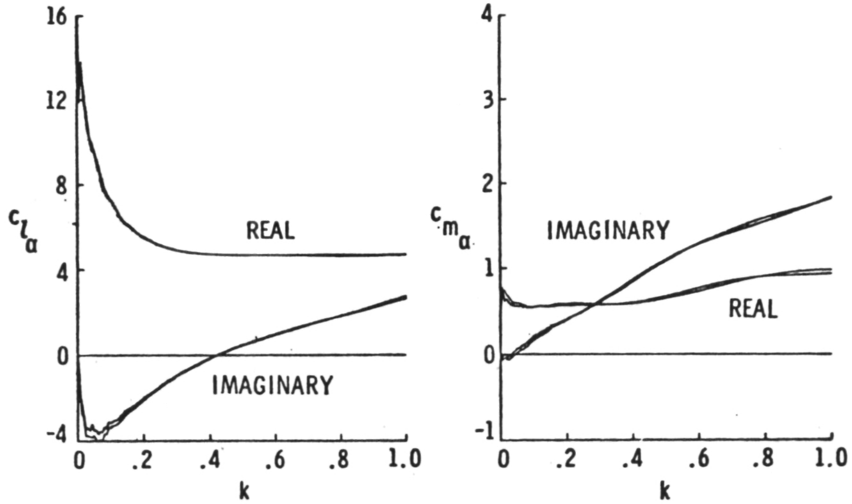
Accomplishment Description - Flutter calculations were made for a 10.6% thick model (64AMES) of the NACA 64A010 and the German design 8.9% thick supercritical MBB-A3 airfoils. The mean angle-of-attack of each airfoil was held fixed and was chosen so that the lift and shock locations were about the same over the Mach number range examined. In the region of the transonic flutter dip (Mach numbers from 0.75 to 0.80), the behavior for the two airfoils was remarkably similar, in spite of their quite different shapes. In fact, when the flutter boundary for the conventional airfoil was shifted by a Mach number of 0.01, the curves were nearly coincident. The figure displays the underlying explanation for this unexpected result. With the 0.01 shift in Mach number, the aerodynamic forces for the two airfoils are virtually identical over the entire range of vibration frequencies (k) shown. Although the static lift and unsteady forces for the two airfoils were very similar, the static pitching moments were quite different. For this reason the static twist behavior of the airfoils under aerodynamic load was quite different.

Future Plans - A systematic study of the effects of airfoil shape, thickness, camber, and angle-of-attack on the unsteady aerodynamic forces is planned.

Figure 35(a).

XTRAN2L RESULTS SHOW TRANSONIC AEROELASTIC EFFECTS ARE LOCALLY LINEAR

64AMES AIRFOIL AT $M = 0.78,\ \alpha_0 = 1^\circ$
MBB-A3 AIRFOIL AT $M = 0.79,\ \alpha_0 = -0.5^\circ$



- TRANSIENT PULSE TECHNIQUE PROVIDES ACCURATE HARMONIC FORCES
- PADE APPROXIMANTS YIELD USABLE s-PLANE FORCES
- FLUTTER BOUNDARIES FOR CONVENTIONAL AND SUPERCRITICAL AIRFOILS WERE SIMILAR WITH A 0.01 MACH NUMBER SHIFT
- UNSTEADY FORCES AND PRESSURES FOR THE TWO AIRFOILS WERE SIMILAR
- STATIC TWIST BEHAVIOR FOR THE TWO AIRFOILS WAS DIFFERENT

Figure 35(b).

UNSTEADY PRESSURE TEST OF DAST ARW-2 SHOWS UNUSUAL TRANSONIC INSTABILITY BOUNDARY

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and

David A. Seidel
Unsteady Aerodynamics Branch
Extension 4236

RTOP 505-33-43

Research Objective - The accurate prediction of aeroelastic effects at transonic speeds for modern aerospace vehicles requires knowledge of the interaction of unsteady aerodynamic loads and elastic deformations. Although unsteady forces and pressures have been measured previously on oscillating rigid surfaces, these results have not provided all of the needed information. Consequently, the present study was undertaken to determine the unsteady aerodynamic characteristics of an elastic wing where the cause and effect relationship between the aerodynamic loading and the elastic deformation can be determined because both quantities are measured.

Approach - NASA's Drones for Aerodynamic and Structural Testing (DAST) program involves flight testing of several Aeroelastic Research Wings (ARW) on a drone aircraft. The ARW-2 right wing is instrumented for unsteady pressure measurements and is flexible enough to require a flutter suppression system. In this project, the right wing panel was recently tested in the Langley TDT. These wind tunnel studies will complement the objectives of the flight program and expedite obtaining measured transonic unsteady pressure data on an aeroelastic wing.

The ARW-2 right wing was installed on the TDT sidewall with a half-body fuselage to simulate the proper flow around the wing root section. The semispan wing was instrumented with 180 pressure orifices and 8 in situ pressure transducers for calibration purposes. Tests were conducted in September, 1983 to obtain the measured transonic unsteady pressures on an aeroelastic wing and to investigate any unknown instabilities which will enhance the safe operation of DAST ARW-2 flights.

Accomplishment Description - Measured pressure data and measured deflection data were obtained for a wide range of wing angle-of-attack, control surface deflection angles and for a large number of tunnel test conditions as shown by the small square symbols in the figure. In addition, an unknown instability was encountered and the boundary defined as shown by the circle symbols. The unstable phenomena (dominated by wing 1st bending motion) does occur above the DAST vehicle's flight regime which is limited to Mach numbers less than 0.86. However, it is of great interest due to the extremely low values of dynamic pressure which occur well below the predicted flutter boundary (shown as a solid line in the figure).

Future Plans - Measured steady and unsteady pressure data is being worked up currently and will be compiled into tabulated form for NASA publication.

Figure 36(a).

UNSTEADY PRESSURE TEST OF DAST ARW-2 SHOWS UNUSUAL TRANSONIC INSTABILITY BOUNDARY

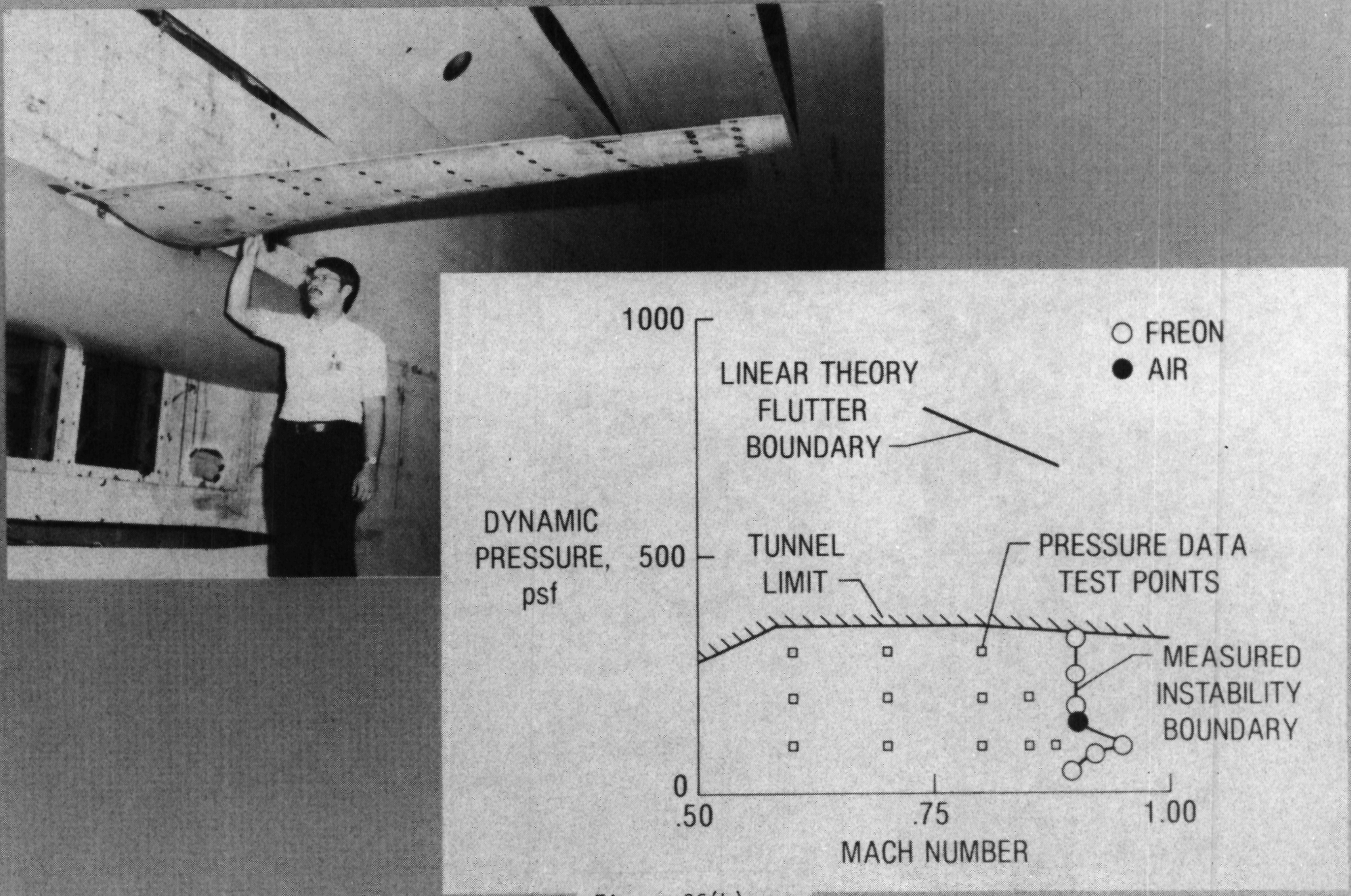
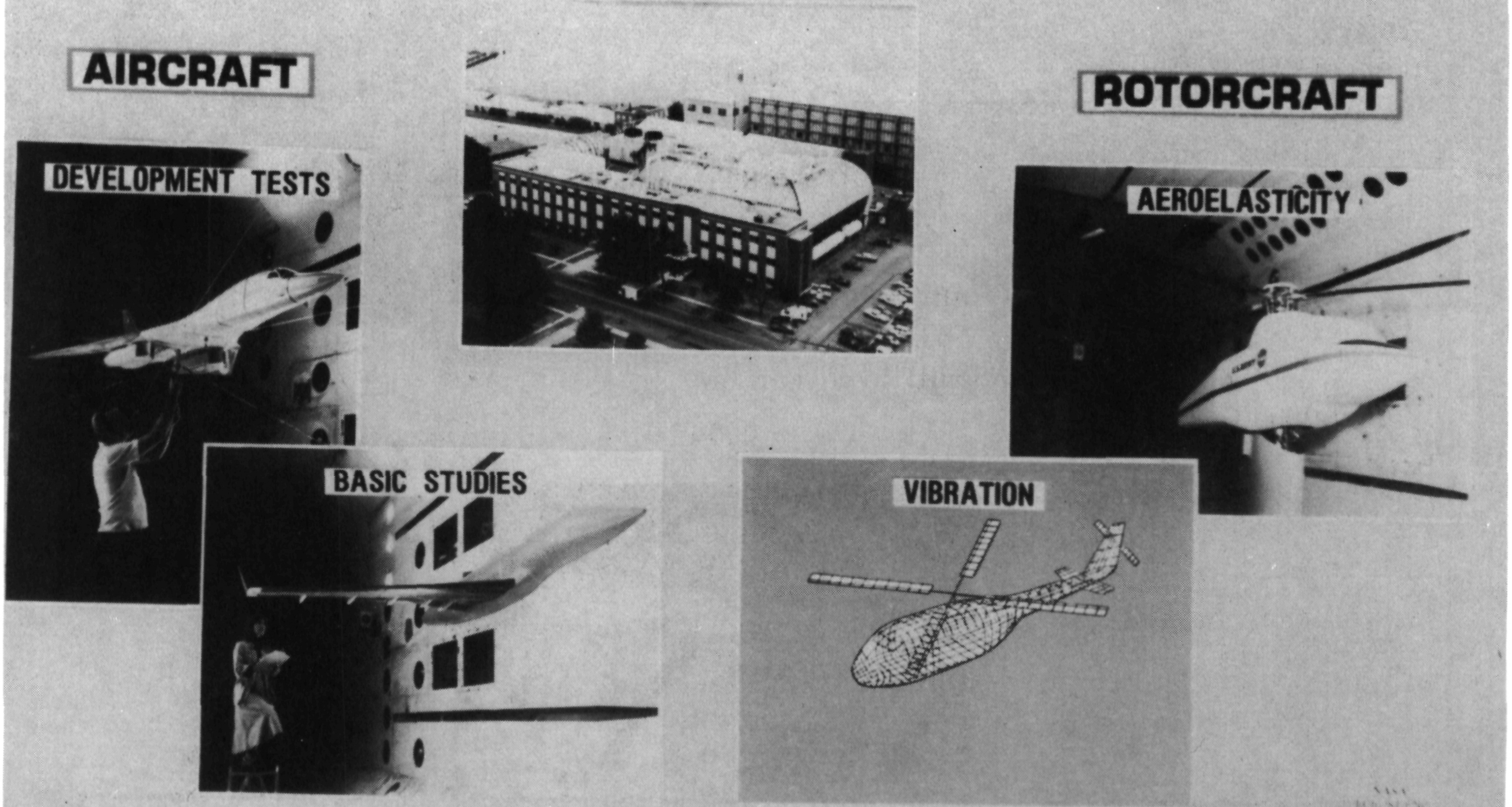


Figure 36(b).

CONFIGURATION AEROELASTICITY



TRANSONIC DYNAMICS TUNNEL

AIRCRAFT

DEVELOPMENT TESTS

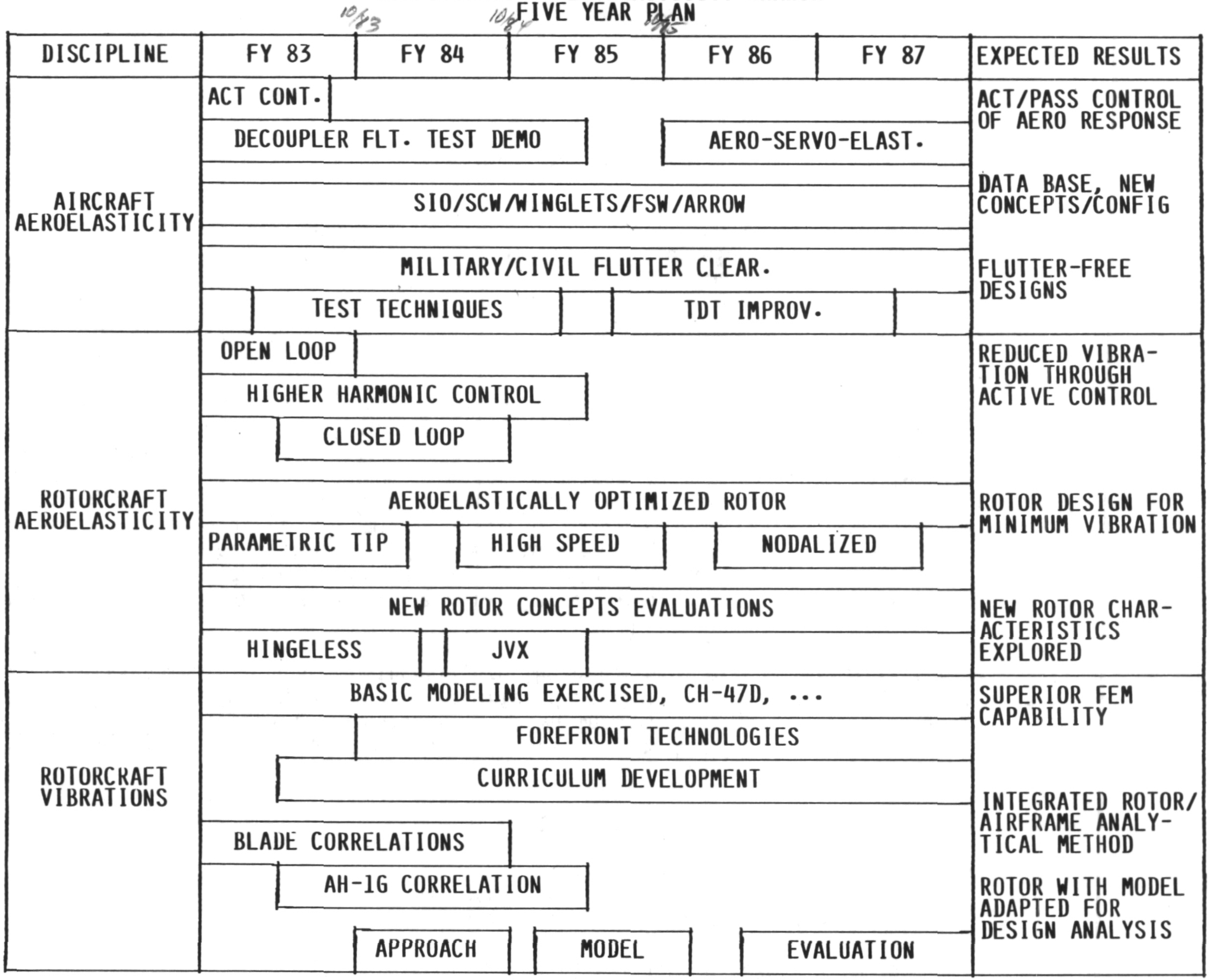
BASIC STUDIES

ROTORCRAFT

AEROELASTICITY

VIBRATION

Figure 37.



CONFIGURATION AEROELASTICITY BRANCH
FIVE YEAR PLAN

Figure 38.

EFFECTS OF NEW FUEL TANKS AND NON-JETTISONABLE PYLONS ON F-16 FLUTTER CHARACTERISTICS DETERMINED IN TDT

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RTOP 505-43-33

Research Objective - The objectives of this test in the Langley Transonic Dynamics Tunnel (TDT) were as follows: 1) to verify analyses which have shown that carriage of certain external stores in combination with new 600 gallon fuel tanks may be restricted by flutter, 2) to investigate possible alternative store carriage arrangements, and 3) to investigate the effects of pylon parameters such as stiffness on flutter speeds.

Approach - A picture of the 1/4-scale F-16 flutter model and external stores used in this test are shown in the accompanying figure. The model was mounted on the two-cable mount system in the TDT and was tested for flutter conditions within the simulated required flight envelope. Several model configurations which included air-to-air missiles and 600 gallon tanks, air-to-air missiles and 370 gallon tanks, and air-to-ground missiles and 600 gallon tanks were investigated for flutter. For those configurations which showed flutter conditions within the required flight envelope, alternative configurations were tested. These alternative configurations included the following fixes: changing the pylon stiffness, disconnecting the aft hook of the pylon, adding ballast to the tip launchers, or moving the missiles further inboard on the wing. Analyses of each configuration were used to guide test procedure.

Accomplishment Description - A total of 32 configurations were tested. Sixteen were basic configurations and 16 were alternative configurations. Test results indicate that the analyses generally predicted the correct flutter mode and frequency. However, the analyses were not as reliable in predicting the flutter speeds. Overall, the analyses were considered a valuable guide. For the majority of the configurations that had flutter conditions within the flight envelope, an alternative configuration was found which would alleviate the problem. For the other cases, valuable experimental data was obtained which can be used in combination with analysis to develop means for eliminating flutter.

Future Plans - Another tunnel test for the F-16 flutter model with the new 600 gallon tanks and store configurations is scheduled for early 1984 to examine additional store configurations.

Figure 39(a).

EFFECTS OF NEW FUEL TANKS AND NON-JETTISONABLE PYLONS ON F-16 FLUTTER CHARACTERISTICS DETERMINED IN TDT

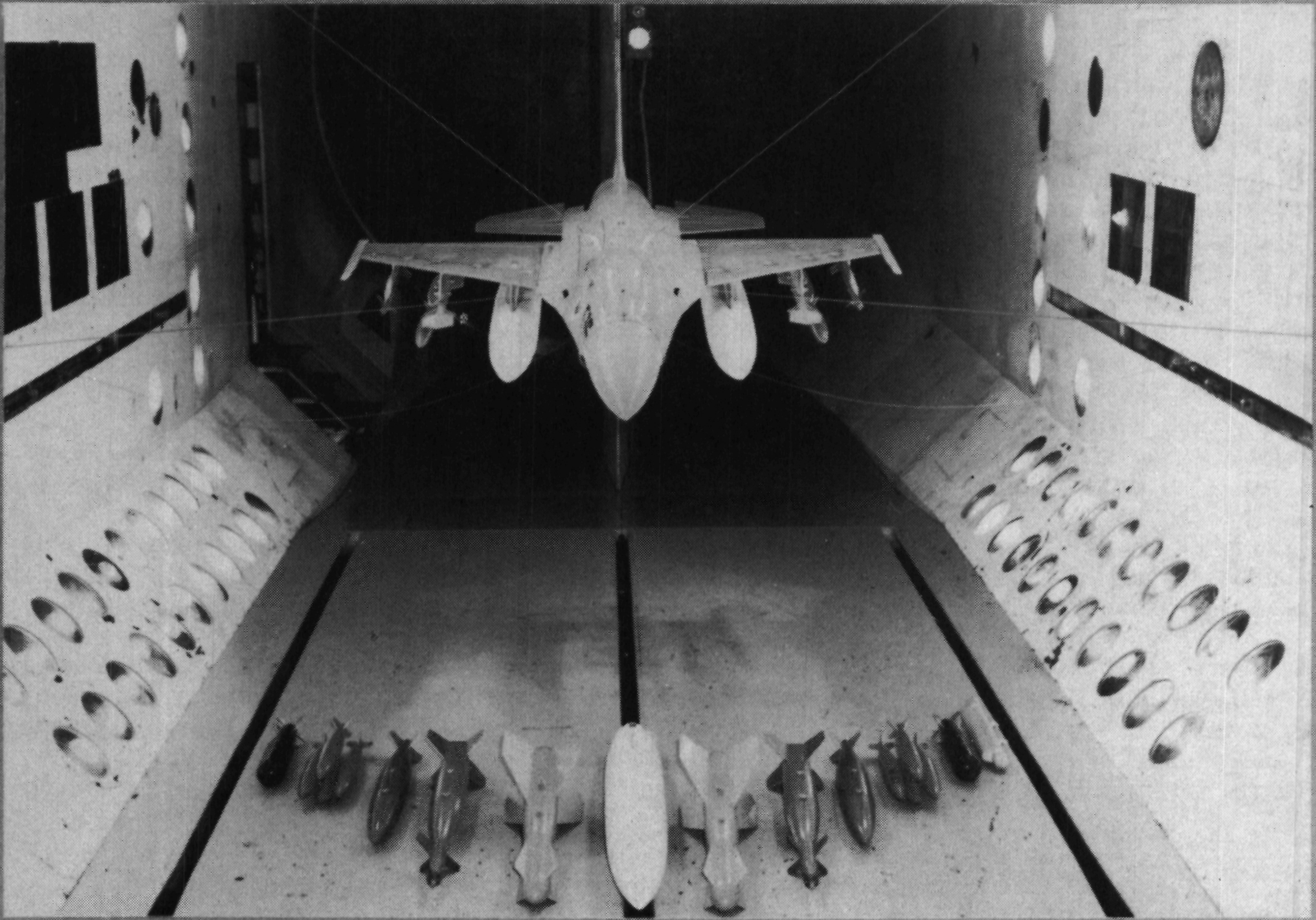

Figure 39(b).

TRANSONIC FLUTTER STUDIES OF EFFECTS OF WINGLETS EXTENDED TO TWIN-ENGINE TRANSPORT TYPE WING

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Configuration Aeroelasticity Branch
Extension 2661

RTOP 505-33-43

Research Objective - Previous transonic studies of the effects of winglets on flutter have been limited mostly to wing configurations without engines. The present study extends this technology base by providing transonic flutter data on a twin-engine transport type wing with winglet. The specific objectives of this study were to determine experimentally the winglet effect on flutter for different variations in configuration parameters and to correlate these results with analysis.

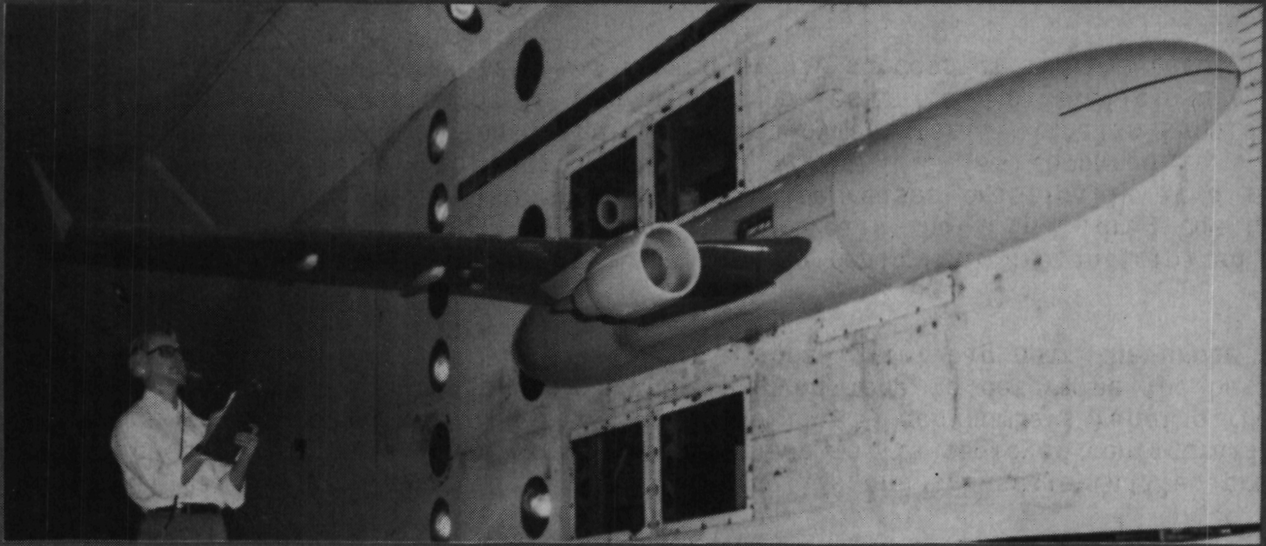
Approach - The present study was a cooperative Boeing/NASA effort. Transonic flutter tests were conducted jointly in the Langley Transonic Dynamics Tunnel (TDT) using an existing, Boeing-built, 1/10-size semispan flutter model of a twin-engine transport type wing. The model is shown cantilever-mounted in the TDT in the figure. The model was equipped with three different wingtips: a nominal wingtip, a tip with a winglet, and a nominally shaped wingtip that was ballasted to simulate the winglet mass properties. Typically, each of the three wing tips were tested as a function of wing fuel loadings, pylon stiffness, and winglet cant angle. In addition, low-speed semispan model tests in the TDT were conducted to determine mass-density ratio effects on winglet flutter.

Accomplishment Description - Transonic flutter boundaries were measured with each of the three wing tips on the following configurations: empty fuel, full fuel, and empty fuel with soft-mounted engine nacelle. As an example of the test results, the winglet effects on the flutter dynamic pressure (q) for the empty wing is shown in the attached figure. The winglet aerodynamic effect (determined by comparing the flutter boundary for the winglet tip with that for the ballasted tip) is much greater than its mass effect and causes a reduction in wing flutter q of about 20 percent near the transonic dip. Other test results obtained include the following: (1) Changing the winglet cant angle from 20° to 0° for the one configuration tested had little effect at the transonic dip but reduced the flutter q slightly at the lower subsonic Mach numbers; (2) In the low-speed model tests, mass-density ratio effects on the flutter dynamic pressure for a wing-with-winglet configuration were determined in air and freon. In general, pre-test analyses were in good agreement with test results.

Future Plans - More exacting, post-test flutter analyses are underway by Boeing using experimentally modified strip theory and by NASA using doublet lattice theory. A future transonic study of a winglet on a multi-engine (two engines per side) transport wing is planned in the TDT as a cooperative McDonnell-Douglas/NASA project.

Figure 40(a).

TRANSONIC FLUTTER STUDIES OF EFFECTS OF WINGLETS EXTENDED TO TWIN-ENGINE TRANSPORT TYPE WING



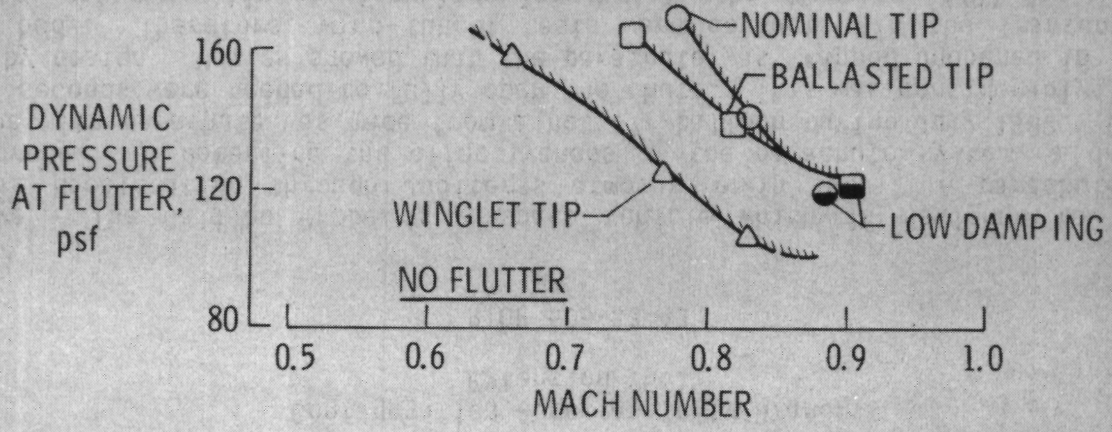


Figure 40(b).

GALILEO PARACHUTE CONFIGURATION TESTED IN TDT

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Extension 2661

RTOP 505-33-43

Research Objective - The Galileo Probe is a space vehicle which is designed to record atmospheric measurements while decelerating through Jupiter's atmosphere in 1989. A parachute will be used to decelerate this probe. To determine the effectiveness of the parachute system, a drop test of a full size Galileo probe with parachute was made from a hot air balloon during July 1982. Upon release of the main parachute, 6 seconds were needed to fully open the chute. This was considerably longer than the 0.5 seconds required by design. Movies showed that the parachute was trapped unopened in the viscous wake of the blount probe body. Therefore, wind tunnel tests were conducted in the Transonic Dynamics Tunnel (TDT) to define the optimum ratio of riser-line length to probe diameter (X/D) for a successful deployment of the parachute.

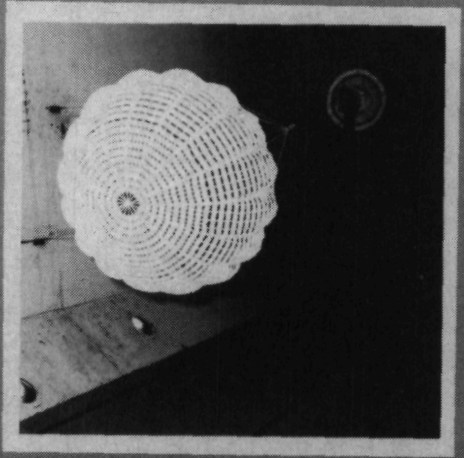
Approach - Wind tunnel tests were conducted in the TDT using 1/4 and 1/2 scale Galileo probes and parachutes. In the attached figure one of the parachutes is shown in its deployed configuration in the TDT. Parachute behavior was investigated for X/D of 5.5, 7, 9 and 11 at Mach numbers ranging from 0.6 to 1.1. Preliminary tests were made with the parachute in the deployed mode to determine the best X/D. During the final tests the parachute was actually deployed from a containment bag near the probe to verify this result.

Accomplishment Description - The maximum loads for the Galileo deployment are anticipated at M=0.95. As shown in the attached figure at this Mach number the data reveals that C_D (drag coefficient) levels off at an X/D of 9; however, the data also show that C_D decreases drastically at a slightly higher Mach number. Taking these factors into consideration an X/D of 8.5 (as compared to 5.5 used in the earlier drop test) was selected for the final wind-tunnel deployment test. It also should be noted that the parachute behavior that was experienced in the first drop test, i.e., partial closure, was simulated during the tunnel tests. The wind tunnel test was deemed highly successful and the results were verified during another subsequent balloon drop test.

Future Plans - The final test of the parachute deceleration system will occur when the Galileo Probe enters Jupiter's atmosphere in 1989.

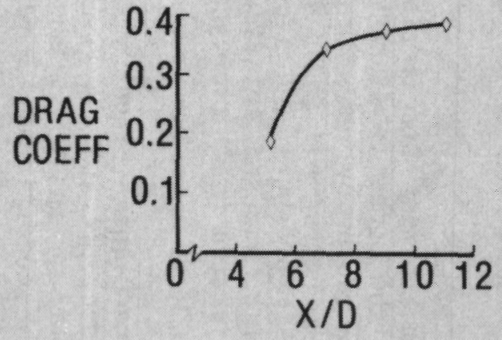
Figure 41(a).

ACCEPTABLE GALILEO PARACHUTE CONFIGURATION DEFINED IN TDT TEST



PARACHUTE INSTALLATION

RISER LINE LENGTH EFFECTS
M=0.95



MACH NUMBER EFFECTS
X/D=9

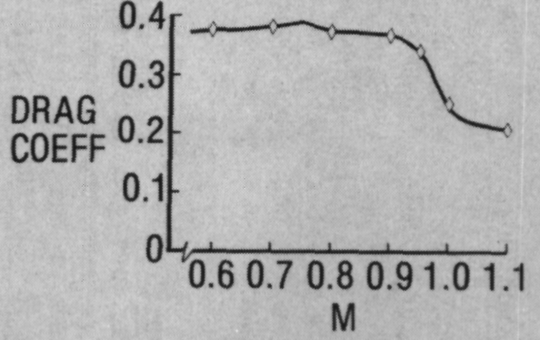


Figure 41(b).

DECOUPLER PYLON FLIGHT TEST CONFIGURATION CLEARED IN TDT

F. W. Cazier, Jr. and Moses G. Farmer
Configuration Aeroelasticity Branch
Extension 2661

RTOP 505-33-43

Research Objective - The Decoupler Pylon is a NASA-patented device for the underwing carriage of stores and passive suppression of wing/store flutter. The concept has been demonstrated in the past with research pylons on several flutter models. Promising results have led to the design and fabrication of flight quality hardware and to the conduct of a near term flight test program using an F-16 airplane under combined RT and RJ funding. The objective of this present study is to evaluate the flutter characteristics of the F-16 with stores on decoupler pylons which have the key features of the flight test hardware.

Approach - A 1/4 scale aeroelastic model of the F-16 with the flight test store configuration was wind tunnel tested in the Transonic Dynamics Tunnel (TDT). In the accompanying figure, the model is shown on the cable mount system in the TDT. The store configuration includes the following: AIM-9J missiles on the wingtips, GBU-8 bombs on decoupler pylons near mid span, and half-full 370 gallon fuel tanks on standard pylons. A 1/4 scale decoupler pylon shown in the insert was fabricated which incorporated the key features of the flight test hardware, namely the 4-bar linkage remote pivot arrangement, damper, and the tapered beam spring. In addition, scaled breakout friction was incorporated in the model pylon because ground tests had revealed significant breakout friction as a result of binding in the flight pylons.

Accomplishment Description - Initially the flutter boundary was determined with the bombs on standard pylons. Then the bombs were mounted on each wing on decoupler pylons with the scaled friction level. The tests were repeated, and the model was shown to be flutter free to 111% above the baseline flutter dynamic pressure. A second study was conducted with the breakout friction varying from no friction to twice the scaled level without observing any degradation in flutter suppression capabilities of the decoupler pylon.

Future Plans - Flight tests of the F-16 airplane with both the standard pylons and decoupler pylons will begin in October 1983. The flutter characteristics of both pylons will be determined in both straight-and-level and maneuvering flight conditions. In addition one GBU-8 will be ejected from a decoupler pylon.

Figure 42(a).

DECOUPLER PYLON FLIGHT TEST
CONFIGURATION CLEARED IN TDT

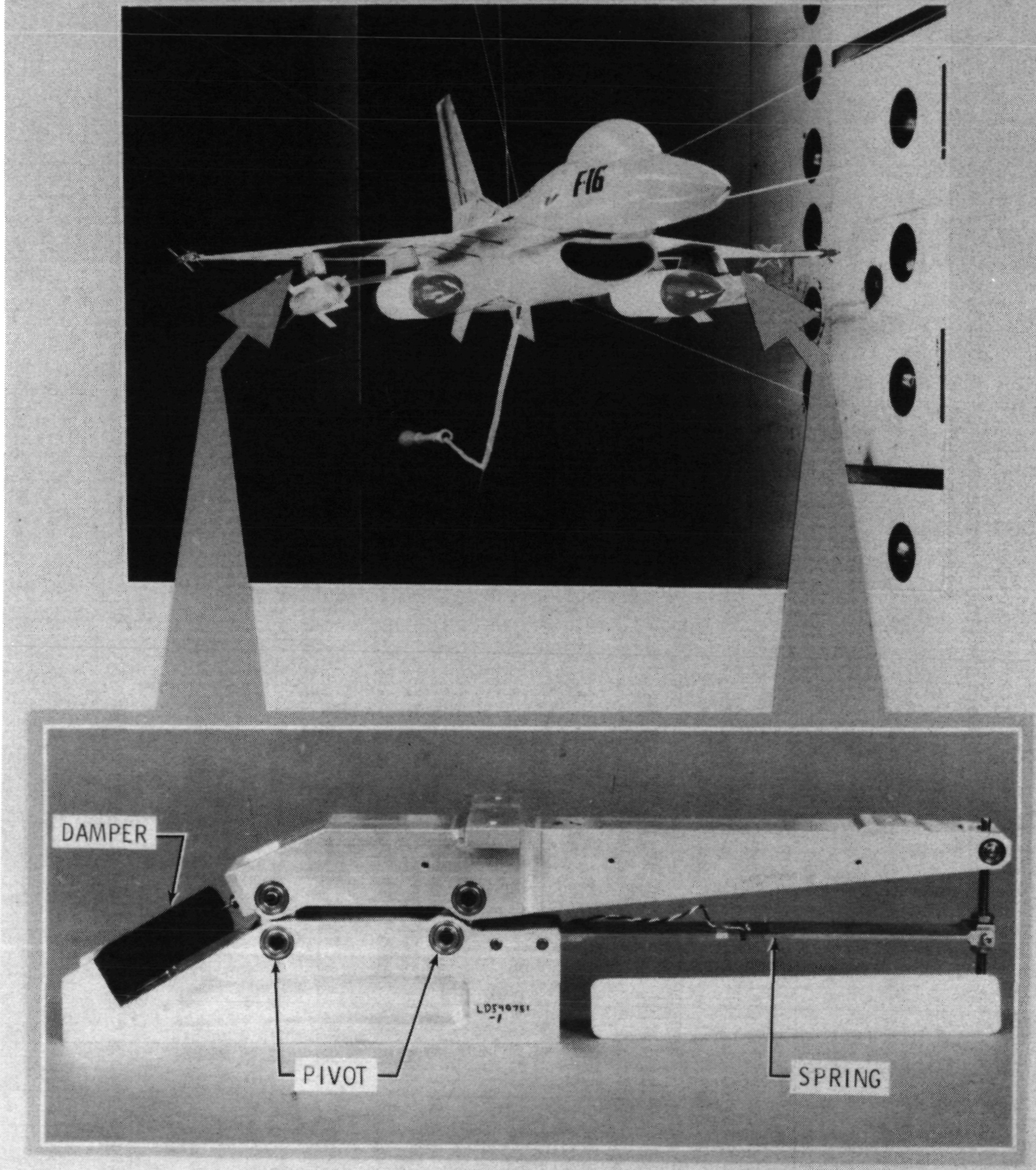


Figure 42(b).

TRANSONIC BODY-FREEDOM FLUTTER ON A FORWARD-SWEPT-WING MODEL MEASURED IN TDT

Rodney H. Ricketts
Configuration Aeroelasticity Branch
Extension 2661

RTOP 505-33-43

Research Objective - Body-freedom flutter is known to be one of the fundamental aeroelastic problems to be avoided on forward-swept-wing (FSW) aircraft. This phenomenon is caused by adverse coupling of rigid-body-pitching and wing-bending motions. Although rare on aft-swept-wing aircraft, this mechanism is generic to FSW configurations due to the tendency of the wing effectively to destiffen (or aeroelastically diverge) with increasing dynamic pressure. A NASA sponsored model test was conducted to investigate this phenomenon of a realistic FSW configuration in the flutter critical transonic speed regime and to ascertain the ability of existing analytical tools to predict its occurrence. The contractual effort with Grumman Aerospace Corporation was primarily funded under RTOP 533-02-83.

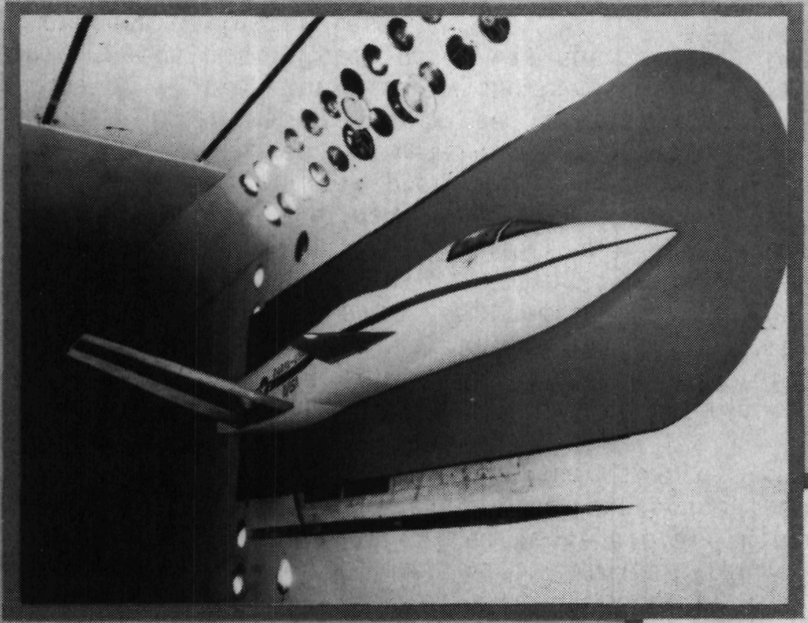
Approach - An 0.5 scale aeroelastic model of a FSW airplane was tested in the NASA Langley Transonic Dynamics Tunnel. The model is shown side-wall mounted in the tunnel test section in the accompanying figure. This model was used during two wind-tunnel tests to acquire the following experimental data: (1) aeroelastic loads and aerodynamic derivatives for various combinations of the wing, body, and canard mounted on a five-component balance, and (2) body-freedom flutter of the model on a mount system that provides rigid-body degrees of freedom. During the second test the model was tested both in a statically stable condition and with relaxed static stability (RSS) up to -25 percent static margin. A stability augmentation system which employed an active canard was used to stabilize the RSS configurations.

Accomplishment Description - Measured and calculated results obtained for the statically stable model configuration are shown in the figure as functions of Mach number and dynamic pressure. The body-freedom flutter calculations as shown proved to be quite unconservative when compared to the measured data. Additionally, a static divergence instability was predicted using a subcritical response technique applied to data measured below the flutter boundary. This instability is shown as the square symbol in the figure. By comparison, the flutter occurred at about 70 percent of the divergence dynamic pressure.

Future Plans - Further work is underway to calibrate the analytical tools so that they will be useful in accurately predicting the body-freedom-flutter phenomenon.

Figure 43(a).

TRANSONIC BODY-FREEDOM FLUTTER ON A FORWARD-SWEPT-WING MODEL MEASURED IN TDT



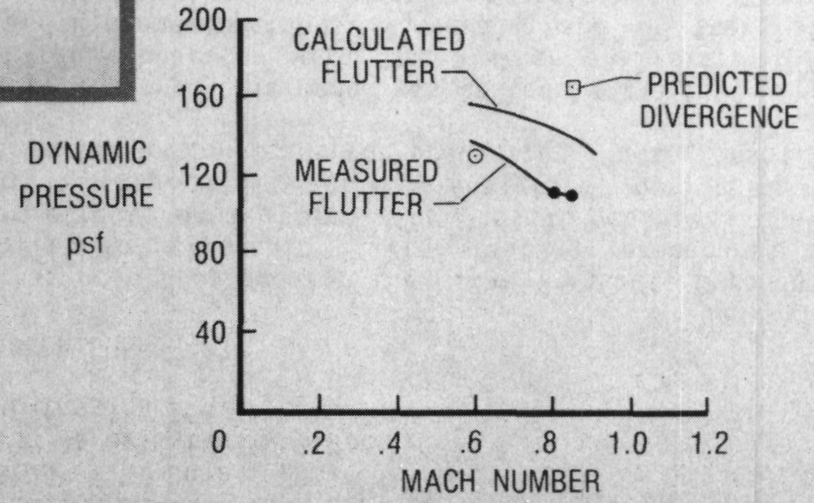


Figure 43(b).

TDT USED TO EVALUATE MODEL FOR FLUTTER TESTING IN HIGH REYNOLDS NUMBER 0.3-METER TRANSONIC CRYOGENIC TUNNEL

Stanley R. Cole
Configuration Aeroelasticity Branch
Extension 2661

RTOP 505-33-43

Research Objective - A cryogenic flutter test has been proposed for the 0.3-m Transonic Cryogenic Tunnel (TCT). This test will determine the feasibility of cryogenic flutter testing, procedures unique to cryogenic flutter testing, and Reynolds number effects on flutter. The present study was conducted in the Transonic Dynamics Tunnel (TDT) to evaluate the validity of the analytical design methods, the flutter behavior of the model, and subcritical response techniques for predicting flutter onset.

Approach - A larger, dynamically similar model of the cryogenic model was tested in the TDT. Frequencies and flutter dynamic pressures were obtained for comparison with the flutter analysis. Subcritical response data were taken using the Peak-Hold and Randomdec methods. Several "hard" flutter points were also obtained to verify the subcritical response techniques. The model was monitored as it experienced oscillatory flutter to determine the character of the flutter and its severity at various Mach numbers.

Accomplishment Description - Analytical methods used to develop the 0.3-m TCT model were shown to be sufficient through evaluation of the TDT model. The analytical flutter boundary in comparison to the measured boundary was conservative and fairly accurate. Frequency comparisons of the primary modes which participated in flutter also compared well. The Peak-Hold subcritical response technique proved to be the most accurate method for predicting flutter onset of the methods tested. The attached figure shows the Peak-Hold method at a Mach number of 0.7. The model response (A) grows to infinity as flutter is approached so that the reciprocal of the response is extrapolated to zero at the flutter dynamic pressure. The subcritical prediction is in good agreement with the "hard" flutter point. The TDT model was visually monitored to determine if flutter was too violent to risk testing in the 0.3-m TCT. Transonic flutter was found to be rather stable in that, as the dynamic pressure was increased, the amplitude of flutter increased without resulting in a divergent oscillation. Flutter was more violent at subsonic speeds but flutter onset was not sudden. These tests showed that this type of model is suitable for a cryogenic flutter test.

Future Plans - The TDT flutter test is complete. The cryogenic flutter model is fabricated and ground vibration tests are now being conducted on the model. Testing in the 0.3-m TCT is scheduled to fulfill the original objectives.

Figure 44(a).

TDT USED TO EVALUATE MODEL FOR FLUTTER TESTING IN HIGH REYNOLDS NUMBER 0.3-METER CRYOGENIC TUNNEL

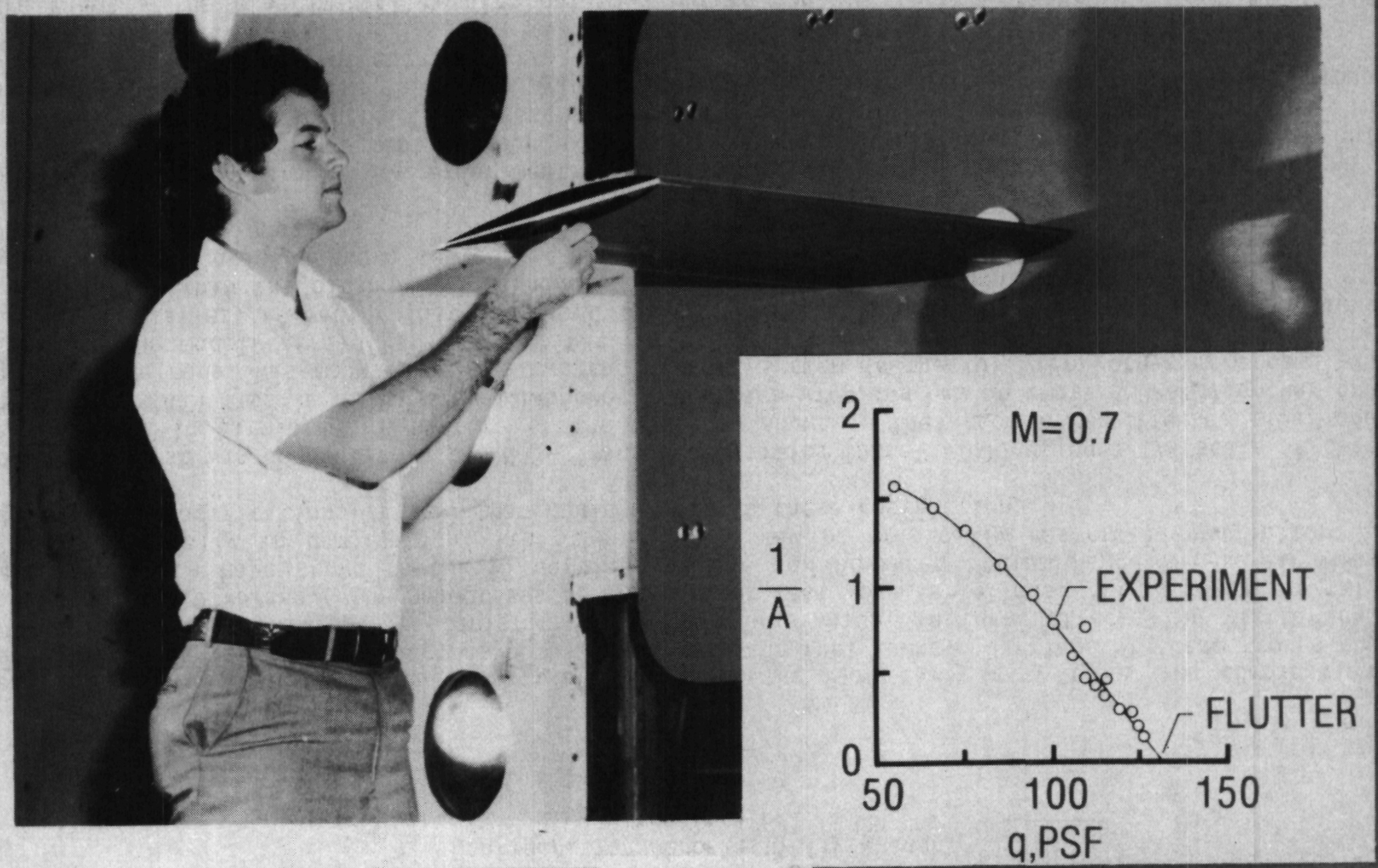


Figure 44(b).

EFFECTS OF NEW AMRAAM MISSILES ON F-16 FLUTTER CHARACTERISTICS STUDIED IN TDT

Moses G. Farmer and Frank W. Cazier, Jr.
Configuration Aeroelasticity Branch
Extension 2661

RTOP 505-43-33

Research Objective - Modern fighter airplanes such as the F-16 carry many types and combinations of external wing-mounted stores: such as bombs, missiles, and fuel tanks. Carriage of these stores changes the dynamic and aerodynamic characteristics of the airplane which, in turn, affects the flutter characteristics of the airplane. The objectives of the current test were as follows: 1) to study the validity of analyses which have shown that F-16 carriage of the new Advanced Medium Range Air-to-Air Missiles (AMRAAM), especially in combination with other stores, may be critically restricted by flutter; 2) to study possible modifications (fixes) that would eliminate these restrictions.

Approach - A test was conducted in the NASA Transonic Dynamics Tunnel (TDT) using a 1/4 scale aeroelastic model of the F-16 airplane. A picture of the model is shown in the accompanying figure. The model is carrying an AMRAAM missile on an AMRAAM launcher under each wing and has an empty AMRAAM launcher on each wing tip. The model was mounted on the two cable mount system in the TDT. For other more complex configurations the model carried various combinations of AIM9J missiles and 370 gallon fuel tanks together with AMRAAM missiles. A factor that increased the number of configurations was that the AMRAAM launcher, which is larger than the older AIM9J launcher, is designed to carry either AMRAAM or AIM9J missiles. A total of 35 configurations were tested. Each configuration was tested for flutter within the required airplane flight envelope.

Accomplishment Description - The experimental results obtained during this test substantiated the need for a flutter fix. The agreement between experimental and analytical results was good for some configurations but not good for others. The reasons for this inconsistancy are not known. Two possible flutter fixes were studied during the test: 1) pylon pitch stiffness was greatly reduced; 2) a small amount of mass was added to the nose of each wing tip launcher. Both of these fixes look promising.

Future Plans - The experimental results obtained during the TDT tests will now be used together with further analyses and flight tests to design a pylon/launcher combination which will be free from flutter for all AMRAAM/store configurations on the F-16 airplane.

Figure 45(a).

EFFECTS OF NEW AIR-TO-AIR MISSILES (AMRAAMS) ON F-16 FLUTTER CHARACTERISTICS STUDIED IN TDT

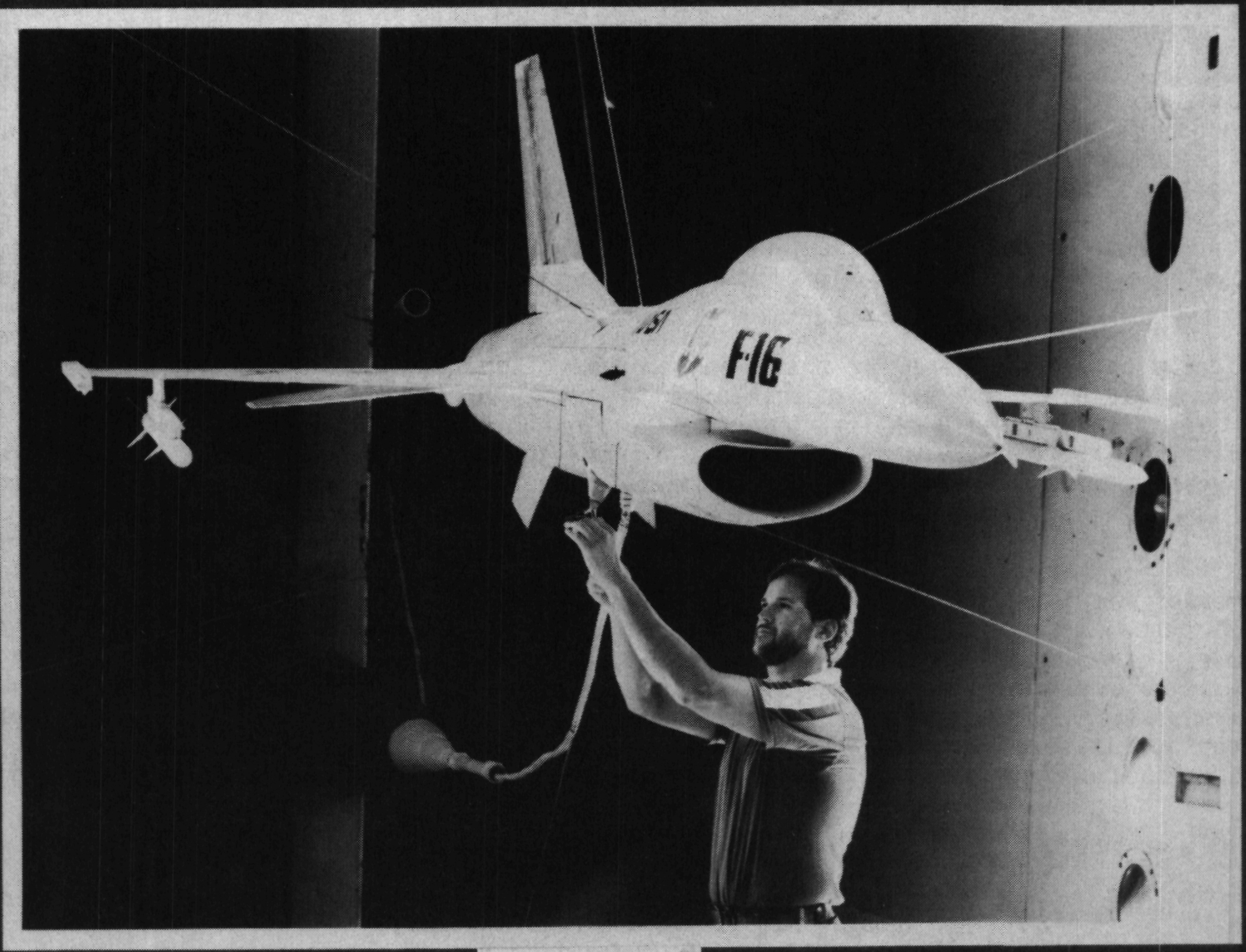


Figure 45(b).

HINGELESS ROTOR EXPERIMENTS VALIDATE ANALYTICAL METHOD

William T. Yeager, Jr., Wayne R. Mantay, and Nabil Hamouda
Configuration Aeroelasticity Branch
Extension 2661

RTOP 505-42-23

Research Objective - One goal of the Aeroelastic Rotor Experimental System (ARES) effort in the Transonic Dynamics Tunnel (TDT) is to develop the capability to successfully test hingeless rotor configurations. An important part of this capability is the prediction of aeromechanical stability characteristics before actual wind-tunnel testing begins. This process of using analysis and testing for rotor stability evaluation is analogous to current practices in fixed-wing flutter research and development. To make pre-test stability predictions and have confidence in them, a reliable analytical method is needed. To determine the suitability of one such analysis, a research program was conducted which involved correlating hingeless rotor in-plane damping predictions with measurements made on the ARES in the TDT.

Approach - The analysis chosen to make the rotor in-plane damping predictions was the Comprehensive Analytical Model of Rotorcraft Aerodynamics and Dynamics (CAMRAD) Program developed at NASA-Ames. Using the measured structural properties of the ARES and the ARES hingeless rotor (AHRO), predictions were made of rotor in-plane damping as a function of rotor RPM and collective pitch for hover in both air and Freon-12, and for forward flight in Freon-12. The damping predictions were made for a baseline rotor configuration as well as for configurations incorporating changes to blade sweep and droop, pre-cone of the blade pitch axis, and blade pitch-flap coupling.

Accomplishment Description - Some illustrative comparisons of experimental and analytical in-plane damping values for both hover and forward flight are shown in the figure. Initial run-up of the AHRO was conducted in air in the Helicopter Hover Facility (HHF). Testing in hover was also conducted in the TDT in air and in Freon-12. Damping measurements were made using the moving-block technique developed at Langley. As shown in the accompanying figure, CAMRAD predictions were in good agreement with the values of damping obtained in hover in Freon-12, accurately predicting the instability that occurred at about 650 rpm. It should be noted that although not shown, similar correlation was obtained between CAMRAD and test data obtained in hover in air. The figure also shows good correlation between CAMRAD and values of in-plane damping obtained in forward flight at an advance ratio of 0.20.

Future Plans - Continued correlation between CAMRAD and AHRO configurations not investigated during this test will be explored. Investigations will be made of AHRO stability at both high rotor thrust conditions and for various rotor trim conditions. This combination of analysis and test will also be used in investigations to develop advanced rotor systems with improved aeroelastic characteristics.

Figure 46(a).

HINGELESS ROTOR EXPERIMENTS VALIDATE ANALYTICAL METHOD

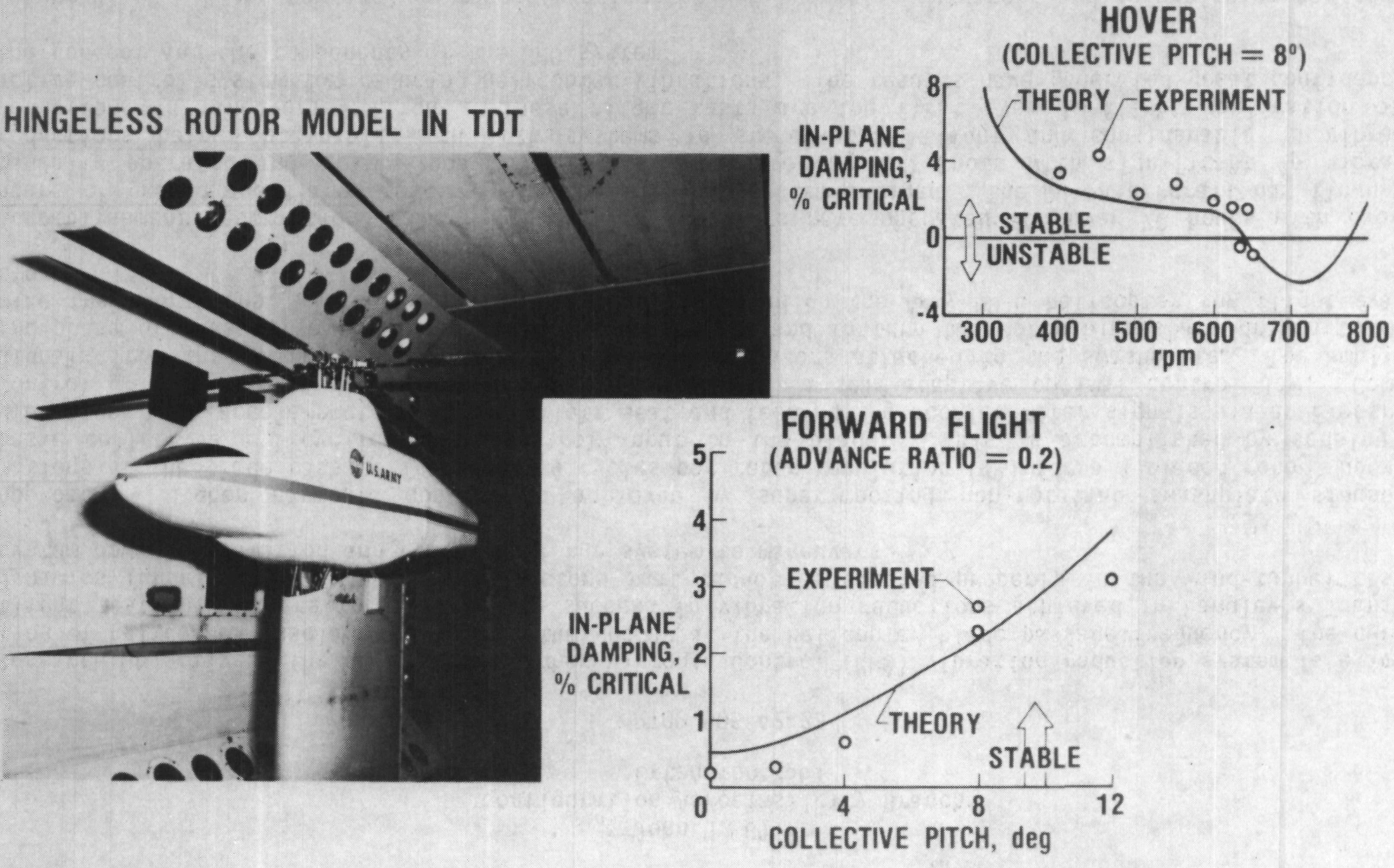


Figure 46(b).

CLOSED-LOOP FLIGHT TEST DEMONSTRATES HIGHER HARMONIC CONTROL (HHC) SYSTEM EFFECTIVE IN REDUCING HELICOPTER VIBRATIONS

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Configuration Aeroelasticity Branch
Extension 2661

RTOP 505-42-23

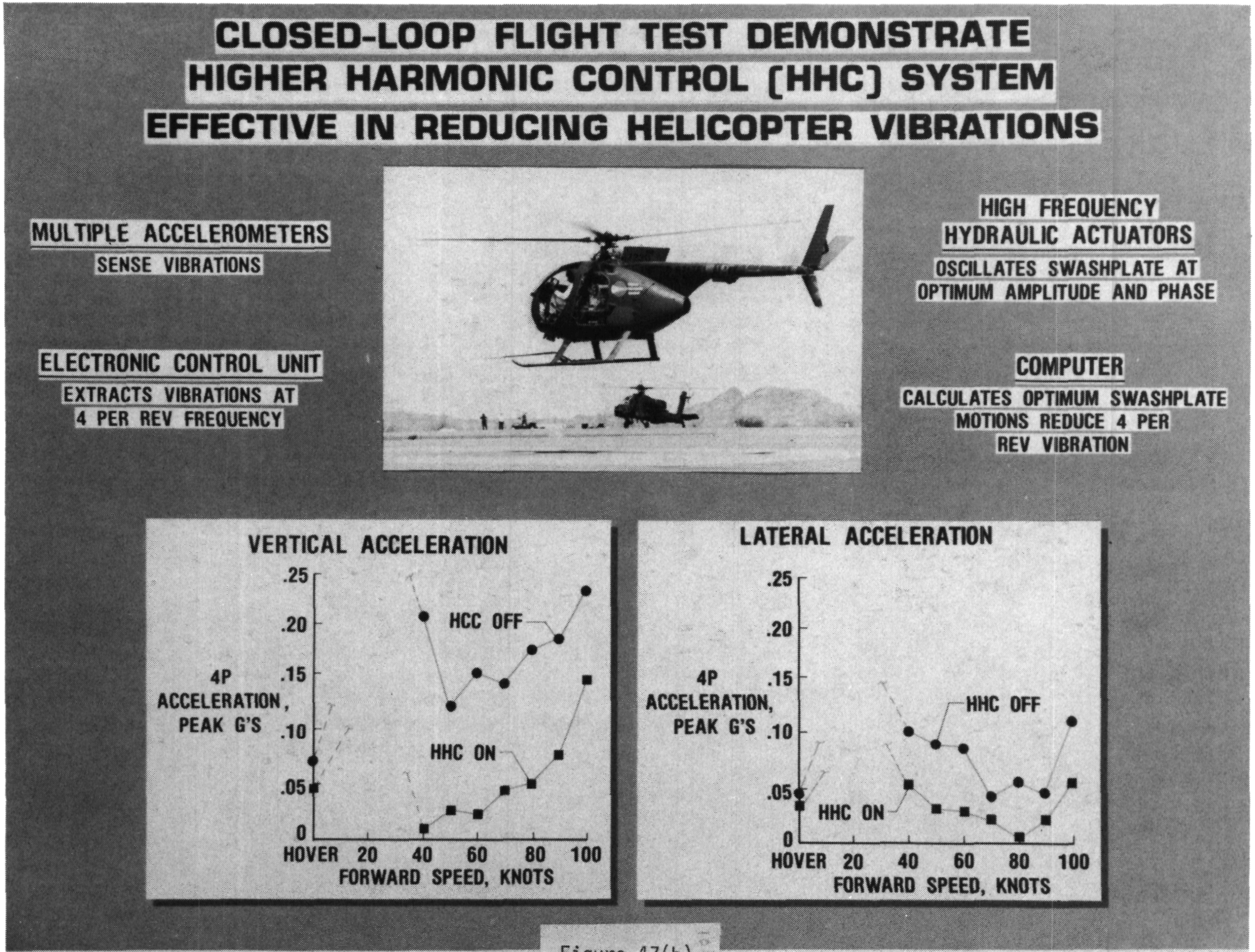
Research Objective - The goal of the Higher Harmonic Control (HHC) vibration reduction system is elimination of helicopter fuselage vibrations that occur at the helicopter blade passage frequency. The current flight tests of HHC are to validate the success in vibration reductions achieved in Langley's Transonic Dynamics Tunnel (TDT) and to assess factors that cannot be studied properly in the wind-tunnel test as system power consumption and reaction of the system to maneuvers.

Approach - Higher harmonic control is achieved by superimposing non-rotating swashplate sinusoidal motions at the blade passage frequency (4 cycles per rotor revolution (4P) for a 4 bladed rotor) upon the basic collective and cyclic flight control input to the blades. This is accomplished by sensing the vibrations with accelerometers at the pilots seat and feeding the accelerometer signals via an Electronic Control Unit back to a digital computer programmed with a self-adaptive optimal control law. Command signals from the computer are routed to hydraulic actuators attached to the swashplate. The amplitude and phase of these signals is such that the swashplate and in turn the rotor blades are driven to minimize the vibrations. This HHC system has been installed on the Army OH-6 helicopter for flight evaluation.

Accomplishment Description - The HHC hydraulic actuators have operated for over 70 hours with over 36 hours of ground and flight testing with the full HHC system engaged. The OH-6A aircraft has flown both manually operated and closed-loop HHC flights from hover to 100 knots with significant 4p vibration reductions being obtainable with both systems in steady-state flight and considerable 4p vibration reductions in maneuvering flight. These flight tests are the first ever in-flight application of an active control system for reducing helicopter vibrations. The results have generated great confidence in the concept and the components of the HHC system.

Future Plans - Plans now include reconditioning the HHC hydraulic actuators and refurbishing the control system bearings and bushings. Also, the flight software will be "fine-tuned". The flight envelope will then be expanded to include all OH-6A maneuvers and transition flight. The logical conclusion of this "proof-of-concept" flight test will be a user/industry technology transfer flight demonstration to be held at Hughes, Mesa, AZ facility.

Figure 47(a).



CLOSED-LOOP FLIGHT TEST DEMONSTRATE HIGHER HARMONIC CONTROL [HHC] SYSTEM EFFECTIVE IN REDUCING HELICOPTER VIBRATIONS

MULTIPLE ACCELEROMETERS

SENSE VIBRATIONS

ELECTRONIC CONTROL UNIT

EXTRACTS VIBRATIONS AT
4 PER REV FREQUENCY

HIGH FREQUENCY HYDRAULIC ACTUATORS

OSCILLATES SWASHPLATE AT
OPTIMUM AMPLITUDE AND PHASE

COMPUTER

CALCULATES OPTIMUM SWASHPLATE
MOTIONS REDUCE 4 PER
REV VIBRATION

Figure 47(b).

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VALIDATED PARAMETERIZED AERODYNAMICS PROCEDURE DEVELOPED FOR ROTOR BLADE DYNAMIC STALL ANALYSIS

Warren H. Young, Jr.
Configuration Aeroelasticity Branch
Extension 2661

RTOP 505-42-23

Research Objective - The purpose of this research is validation of a method for systematic conversion of the immense amounts of data generated from oscillating-airfoil, dynamic stall tests into a form that can be utilized in rotor aeroelastic analyses in a practical manner. Although other methods have been proposed for performing this synthesis, they have all suffered from deficiencies which have severely limited their applicability to practical problems.

Approach - The basis of the present approach is a parameterized method developed by Dr. Richard Bielawa and Dr. Santu T. Gangwani at United Technologies Research Center (UTRC). The present research, under contract NAS1-16803 with UTRC, was carried out in cooperation with the Army Aeromechanics Laboratory at Ames. Dynamic stall data from 17 wind-tunnel tests were obtained for application of the synthesization process. Some generality was insured because this data was for six different airfoils and came from four different wind tunnels. The process of generating the predictive equations and validating them is illustrated in the figure. The basis of this method is a set of algebraic equations containing parameters whose values are determined from the airfoil data. A non-linear least squares curve-fit is used to determine the values of the parameters. With the dynamic stall cycle separated into three parts (unstalled, stalled and stall recovery), these parameters can be used to determine lift, pitching moment and pressure drag for each part based on the angle-of-attack time history and pitch rate. The values of these parameters and the synthesizing equations are used in a time-marching rotor aeroelastic analysis. This approach eliminates table look-up from the data for the unsteady or time-dependent part of the data. The usual static airfoil data tables are still required because static airfoil data for rotor calculations are (and need to be) much more accurate than unsteady measurements, especially for drag.

Figure 48(a).

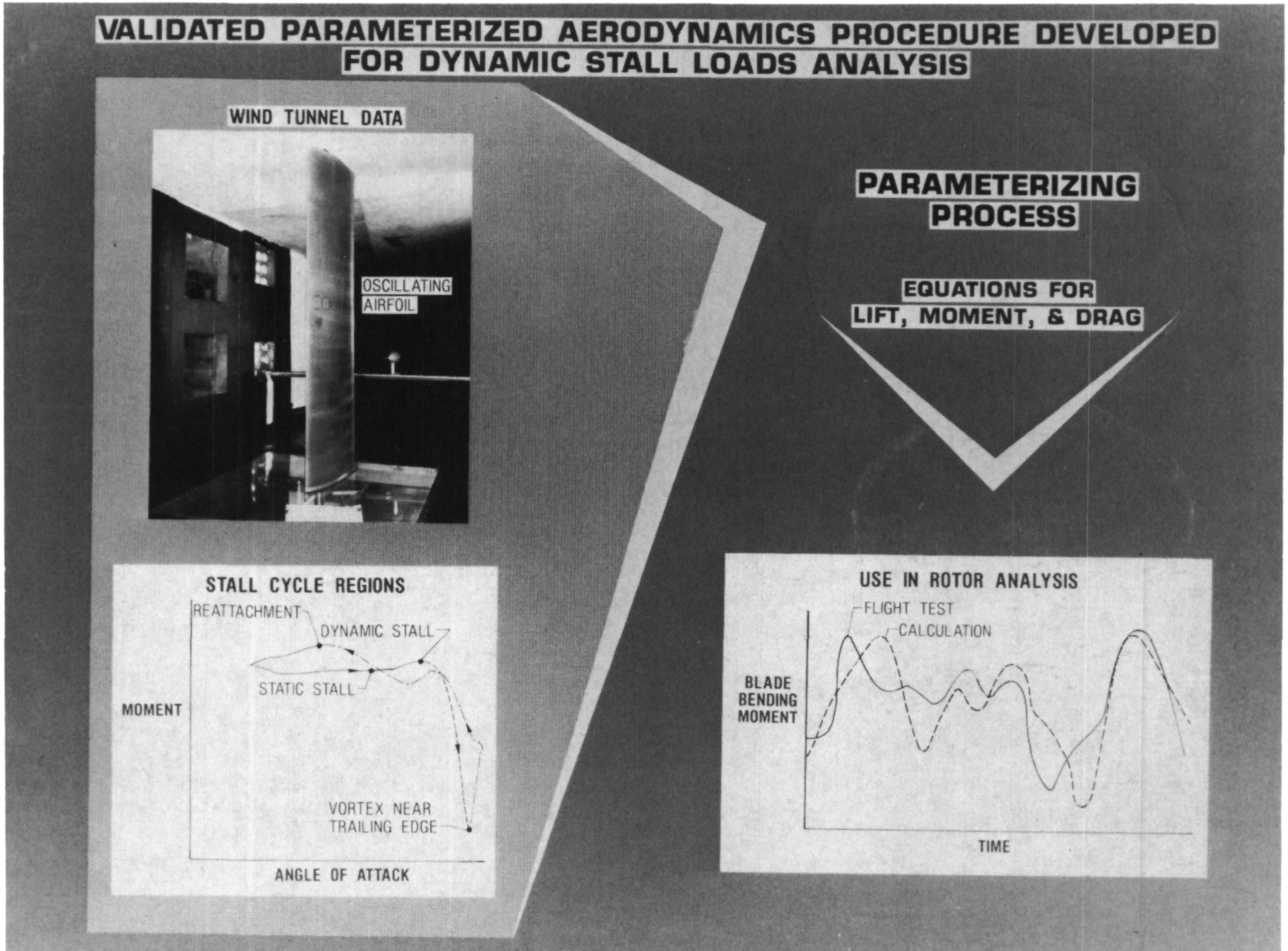
VALIDATED PARAMETERIZED AERODYNAMICS PROCEDURE DEVELOPED FOR ROTOR BLADE DYNAMIC STALL ANALYSIS

Continued

Accomplishment Description - Results indicate that this method is the most efficient means yet developed for converting wind-tunnel dynamic stall data into parameteric form for synthesizing dynamic stall data for rotor aeroelastic analyses. The purposes of this research have been met by demonstrating that a good data fit could be obtained and a satisfactory synthesis made using a selection of parameters for all 17 cases. A brief but successful validation of the method was accomplished by using both flight test and wind tunnel data. An illustrative example of the correlation of calculated results with flight test results is shown in the figure.

Future Plans - The results will be published in a NASA contractor report. The method will be incorporated into the Army Structures Laboratory rotor vibration program, SYMVIBE, now implemented on the Langley computers. The data from the Large Scale Oscillator Rig tests in the Transonic Dynamics Tunnel will be parameterized to extend the data base to two new airfoils at realistic Mach and Reynolds numbers.

Figure 48(b).



VALIDATED PARAMETERIZED AERODYNAMICS PROCEDURE DEVELOPED FOR DYNAMIC STALL LOADS ANALYSIS

WIND TUNNEL DATA

PARAMETERIZING PROCESS

EQUATIONS FOR
LIFT, MOMENT, & DRAG

STALL CYCLE REGIONS

USE IN ROTOR ANALYSIS

Figure 48(c).

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CH-47D MEASUREMENT/ANALYSIS CORRELATION ENHANCES CONFIDENCE IN USE OF FINITE ELEMENT MODELS FOR PREDICTING HELICOPTER AIRFRAME VIBRATIONS

E. C. Naumann, R. G. Kvaternik and W. C. Walton, Jr.
Configuration Aeroelasticity Branch
Extension 2661

RTOP 532-06-13

Research Objective - Currently, mathematical models based on the finite element method of structural analysis as embodied in the NASTRAN computer code are widely used by the helicopter industry to calculate static internal loads and vibrations of airframe structures. The internal loads are routinely used for sizing structural members. However, vibrations predictions are not yet relied on much during design. Advisory groups have indicated a need for NASA to work with the helicopter industry to engender the needed trust in vibrations predictions using these models. The objective is to establish industry-wide a body of modeling guides which will enable future confident prediction of airframe vibrations as part of the regular structural design process.

Approach - Langley Research Center has sponsored the Boeing Vertol Company to conduct an application of the finite element method with emphasis on predicting structural vibrations. The company's production CH-47D helicopter is used as the modeling subject. To assure the necessary scientific controls, the following seven steps were specified: (1) Develop guides for forming a finite element model of the subject airframe under the conditions of a design project, giving attention to modeling techniques and, as well, to organization, cost and schedule to do the modeling work, (2) Present the modeling guides to the other regular U.S. manufacturers of helicopter airframes for critique, (3) Form a finite element model of the subject airframe according to the understood guidelines, (4) Define requirements for vibration measurements and for correlations of analysis with measurements to evaluate the finite element model, (5) Submit the test requirements to the other companies for critique, (6) Carry out the test correlation program according to the understood requirements, and finally (7) Implement an evaluation of the test-correlation results by the participating companies.

Figure 49(a).

CH-47D MEASUREMENT/ANALYSIS CORRELATION ENHANCES CONFIDENCE IN USE OF FINITE ELEMENT MODELS FOR PREDICTING HELICOPTER AIRFRAME VIBRATIONS

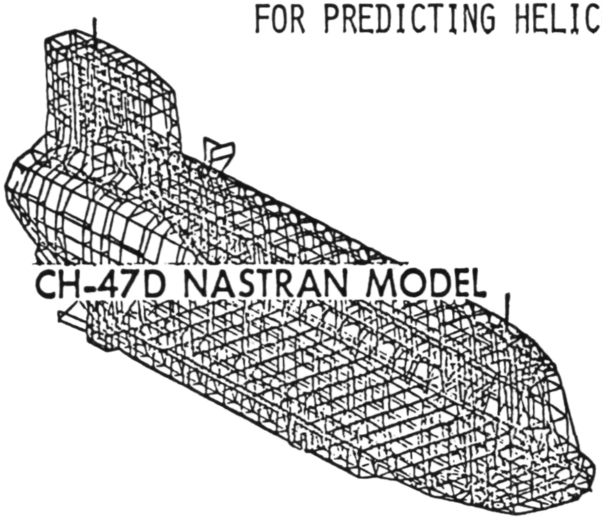
Continued

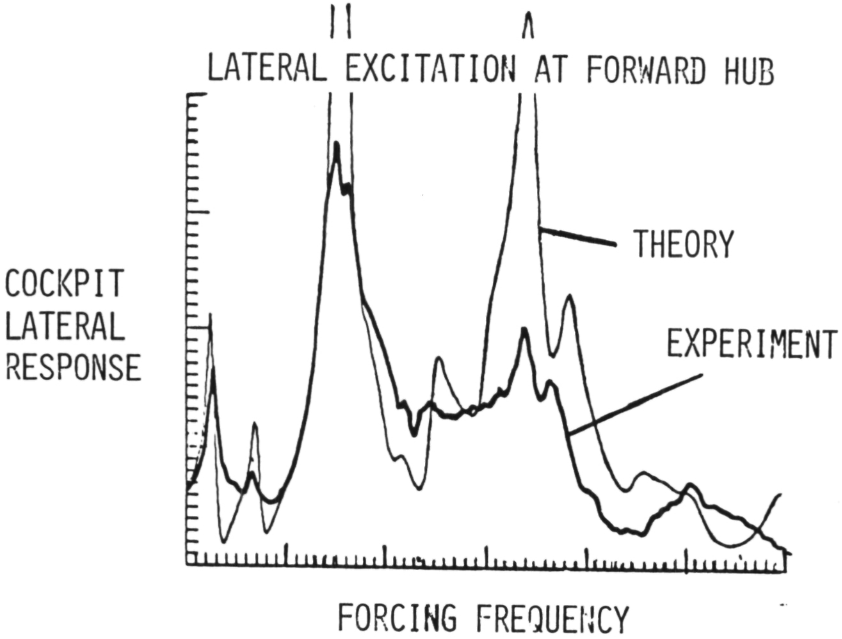
Accomplishment Description - This project has recently been completed. Illustrative examples of calculated and measured frequency response functions are shown in the figure. The correlations which have been obtained are considerably improved over similar attempts of the past and go a long way toward removing uncertainty about the limits of applicability of finite element models for vibrations prediction.

Future Plans - Although the correlations have been considerably improved, it has become clear that what is needed is more hands-on experience throughout the industry. The approach developed here has been adopted as a basis for a major new industry-wide program intended to provide this experience. Under this program, the finite element method will be applied by industry teams to calculate the vibration characteristics of a number of extant helicopter airframes of both metal and composites construction. The analytical results will be evaluated by comparison with results obtained by laboratory vibration measurements.

Figure 49(b).

CH-47D MEASUREMENT/ANALYSIS CORRELATION ENHANCES CONFIDENCE IN USE OF FINITE ELEMENT MODELS FOR PREDICTING HELICOPTER AIRFRAME VIBRATIONS





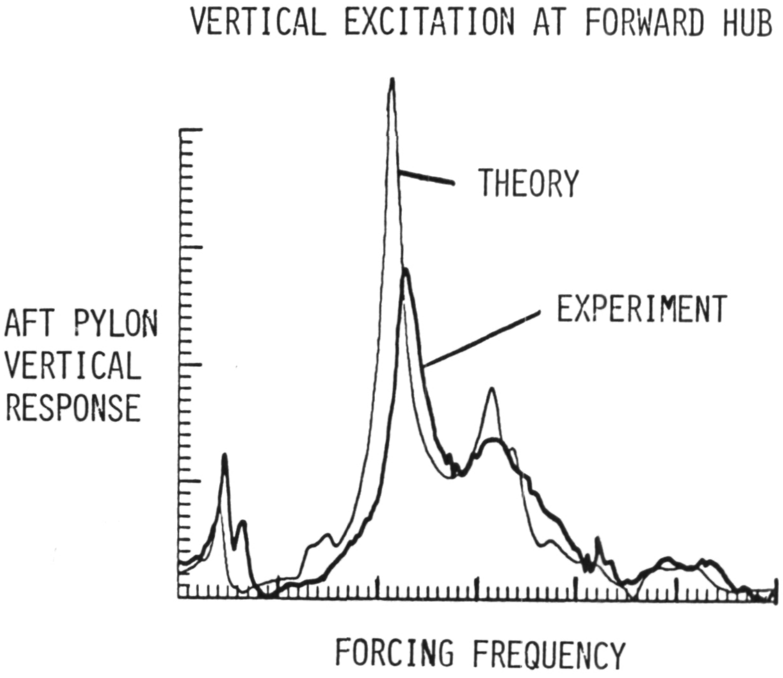


Figure 49(c).

CORRELATION OF ANALYTICAL AND EXPERIMENTAL VIBRATION CHARACTERISTICS OF FULL-SCALE HELICOPTER BLADES ROTATING IN A VACUUM

E. C. Naumann
Configuration Aeroelasticity Branch
Extension 2661

RTOP 532-06-13

Research Objective - The ability to analytically model helicopter rotor blades and hubs accurately is essential if flight loads and vibration levels are to be reliably predicted. The objective here is to establish the accuracy to which rotor blade natural vibration characteristics can be predicted by finite-element modeling methods.

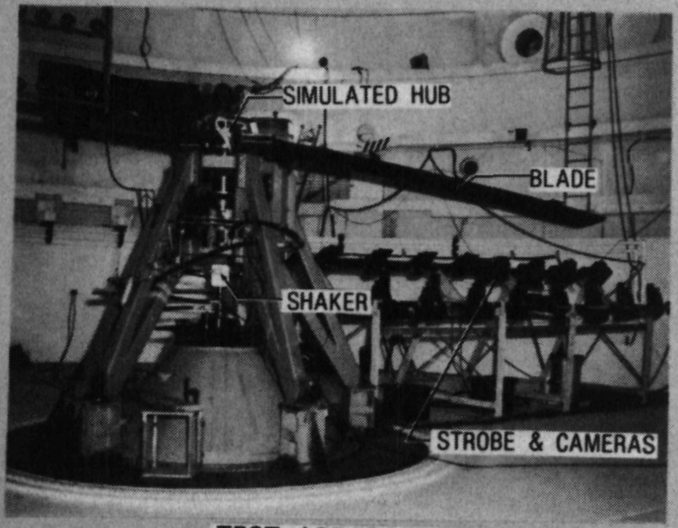
Approach - Vibration modes and frequencies were measured for a system of two full scale UH-1D helicopter blades and a simulated hub in a large vacuum chamber. The tests were conducted in a vacuum to eliminate aerodynamic effects on the measured vibration characteristics. While applying vertical oscillatory loads to the simulated hub, mode shapes of one of the blades were measured photographically for comparison with calculated values. Approximately six modes were measured at each of four rotational speeds (0, 50, 100, and 150 rpm). Analytical values for each of the experimental conditions were calculated using the NASTRAN finite element computer code.

Accomplishment Description - The photo in the figure shows the test apparatus used to obtain frequency and mode shape data. The NASTRAN finite-element model was developed using calculated mass and stiffness properties of the experimental system. It was found that the calculated vibration results were sensitive to the structural representation used in the blade root region as well as mass and structural representation of the simulated hub and blade attachments. In addition, the agreement between theory and experiment was improved by including shear effects in the beam elements (NASTRAN CBAR)used to model the rotor blades. The data shown in the lower portion of the figure are some typical comparisons of calculated (shear effects included) and measured mode shapes. These results are for the 3rd-flap mode. Corresponding natural frequencies are also shown.

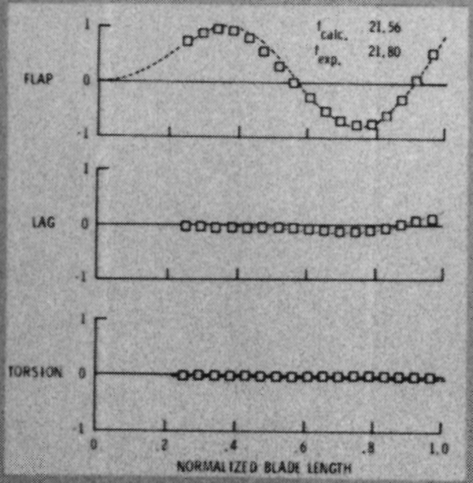
Future Plans - Results of this research will be published as a formal NASA publication. The results will be integrated into the NASA-Industry program to improve vibration prediction and finite-element modeling capability.

Figure 50(a).

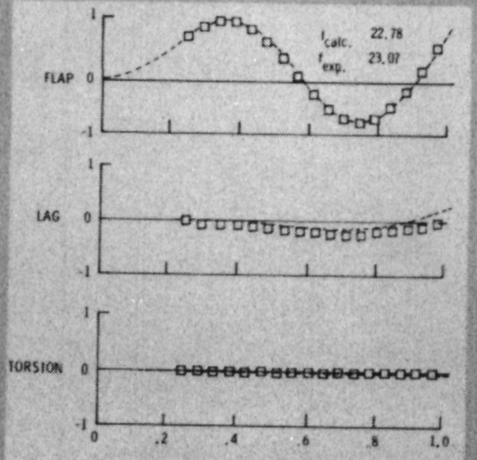
CORRELATION OF ANALYTICAL AND EXPERIMENTAL VIBRATION CHARACTERISTICS OF FULL-SCALE HELICOPTER BLADES ROTATING IN A VACUUM



TEST APPARATUS



"o" RPM RESULTS



100 RPM RESULTS

Figure 50(b).

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CURVED METALLIC TPS

John L. Shideler
Aerothermal Loads Branch
Extension 3423

RTOP 506-53-33

Research Objective - While much of the surface of a typical Space Transportation System (STS) is flat or nearly flat, some areas are necessarily curved. Wind tunnel test data for flat metallic Titanium Multiwall (Ti M/W) and Superalloy Honeycomb (SA/HC) prepackaged TPS have indicated that heating in the gaps between panels can occur and that surface pressure gradients increase the severity of gap heating. Also, analysis indicates thermal stresses are much higher for curved TPS than for flat TPS. The objective is to fabricate curved SA/HC panels to confirm that fabrication of panels is feasible, to test the panels under pressure gradient conditions, and to assess the severity of thermal stresses in curved panels.

Approach - The feasibility of fabricating curved TI M/W panels has been demonstrated as indicated at the left of figure 51(b) which shows a panel with a radius of 12 inches. The sketch to the right shows an array of curved SA/HC panels which will be fabricated for testing on the Curved Surface Test Apparatus (CSTA). The radii of the panels will vary from 9 inches to 12 inches. A section of the CSTA will be cut out so that the curved array can be inserted flush with the CSTA skin. Wind tunnel tests in the LaRC 8' HTT will provide temperature and pressure data to allow evaluation of gap heating. A single curved panel (not shown) will be fabricated, instrumented with strain gages and thermocouples, and tested under radiant heating to evaluate thermal stresses.

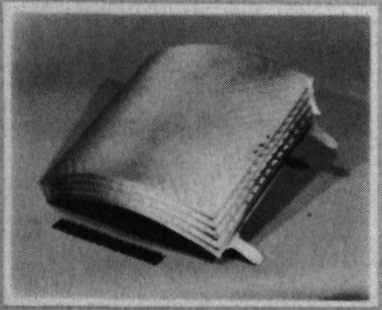
Status/Plans - Figure 51(c) shows an Inconel 617 subassembly laid up for brazing. The side closures, skins, honeycomb core, and through-panel-fastener housing are coated with AMI DF-9N-B2 braze alloy and tack welded in place. A metal bag is inserted and filled with tungsten pellets to provide contact force during brazing. The panel is placed on a carbon block machined to the outer surface contour, and the assembly is placed in a vacuum furnace at 2150^{o}F for 10 minutes and 1950 for 1 hour. The outer surface of the panel is shown at the right after brazing. In a separate operation, a curved titanium honeycomb panel is LID-brazed in a vacuum at 1700^{o}F for 90 minutes, and in a final process, the Inconel 617 subassembly and the titanium panel are joined by LID brazing at 1700^{o}F for 90 minutes. Several individual panels have been fabricated. Even though results from earlier tests of 1st generation titanium multiwall panels indicate a flow angle of 30^{o} will prevent gap heating, flow stoppers will be added to the panel corners to reduce flow in the gaps. The array is scheduled for delivery to NASA - LaRC in March 1984.

Figure 51(a).

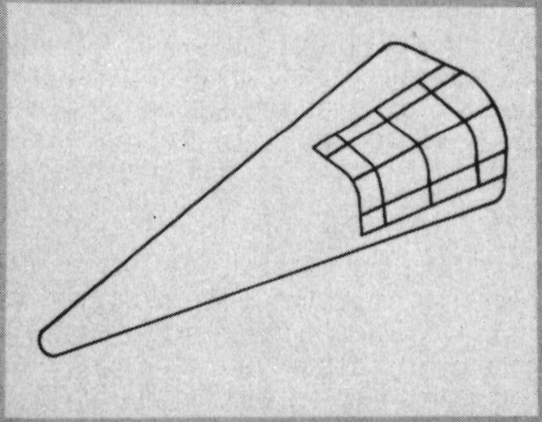
NASA
L-83-2,082

EVOLUTION OF CURVED PREPACKAGED METALLIC TPS

CURVED TITANIUM PANEL



CURVED SUPERALLOY ARRAY



CURVED SURFACE TEST APPARATUS (CSTA)

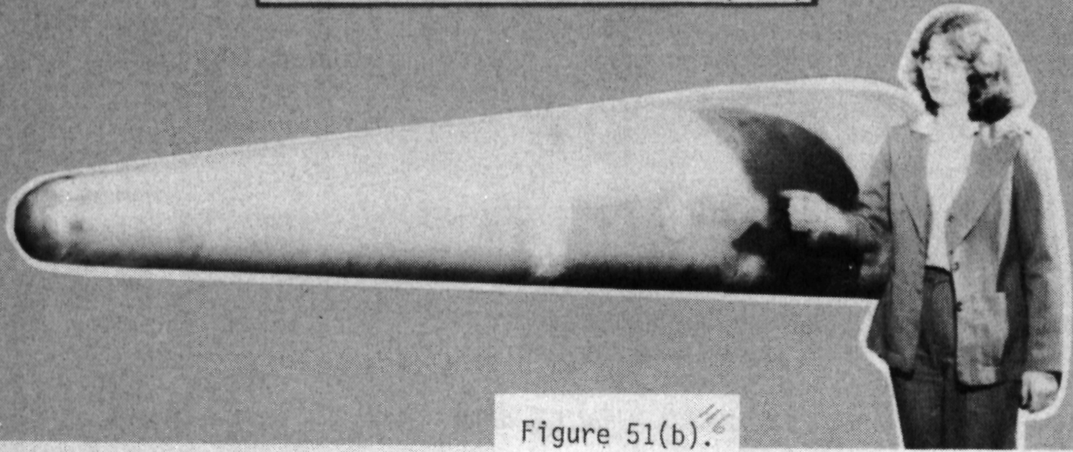


Figure 51(b).

INCONEL 617 CURVED SUBASSEMBLIES LAID UP FOR BRAZING

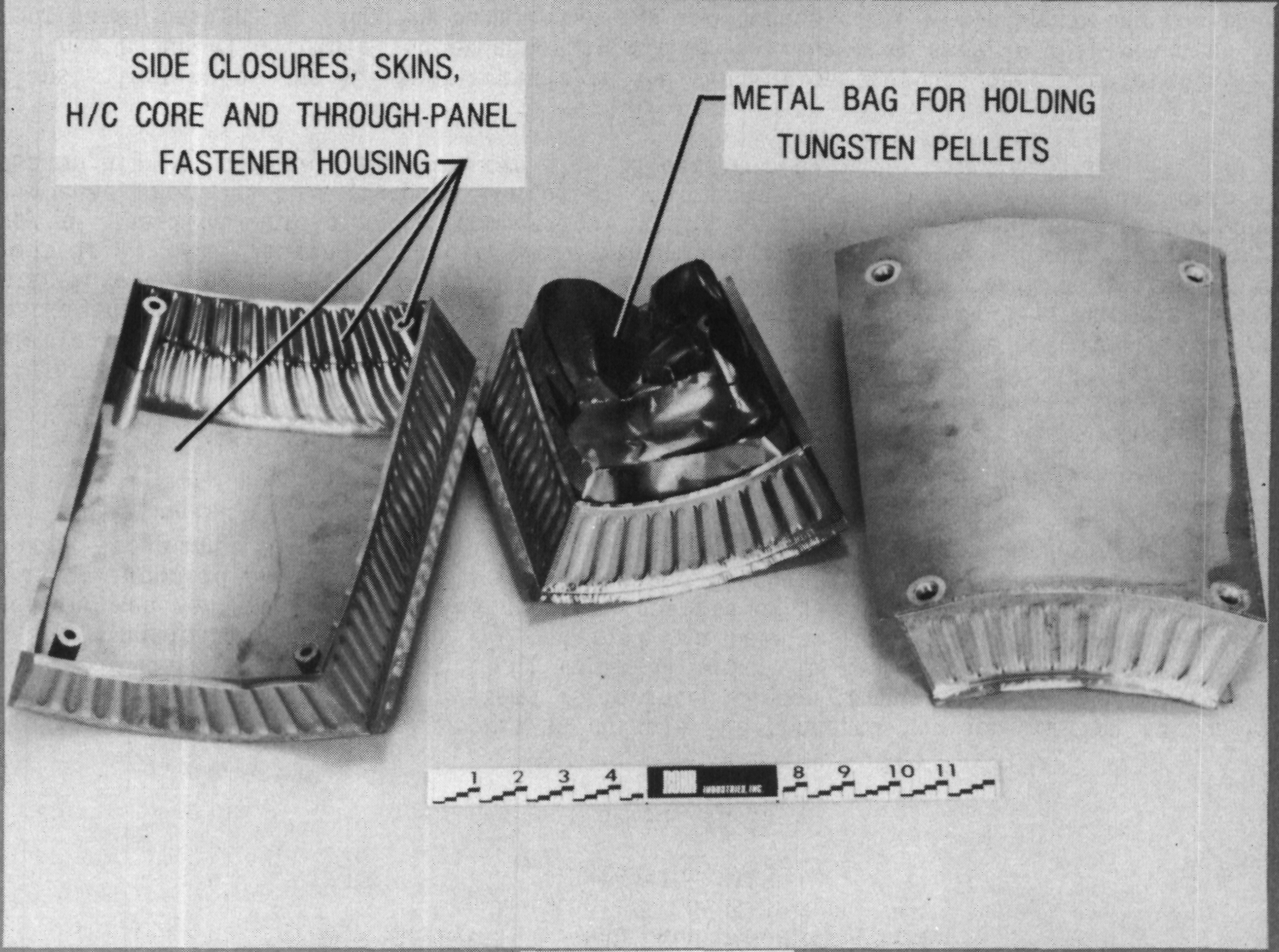


Figure 51(c).

ADVANCED CARBON-CARBON HEAT SHIELD RESEARCH

Granville L. Webb and Claud M. Pittman
Aerothermal Loads Branch
Extension 2425

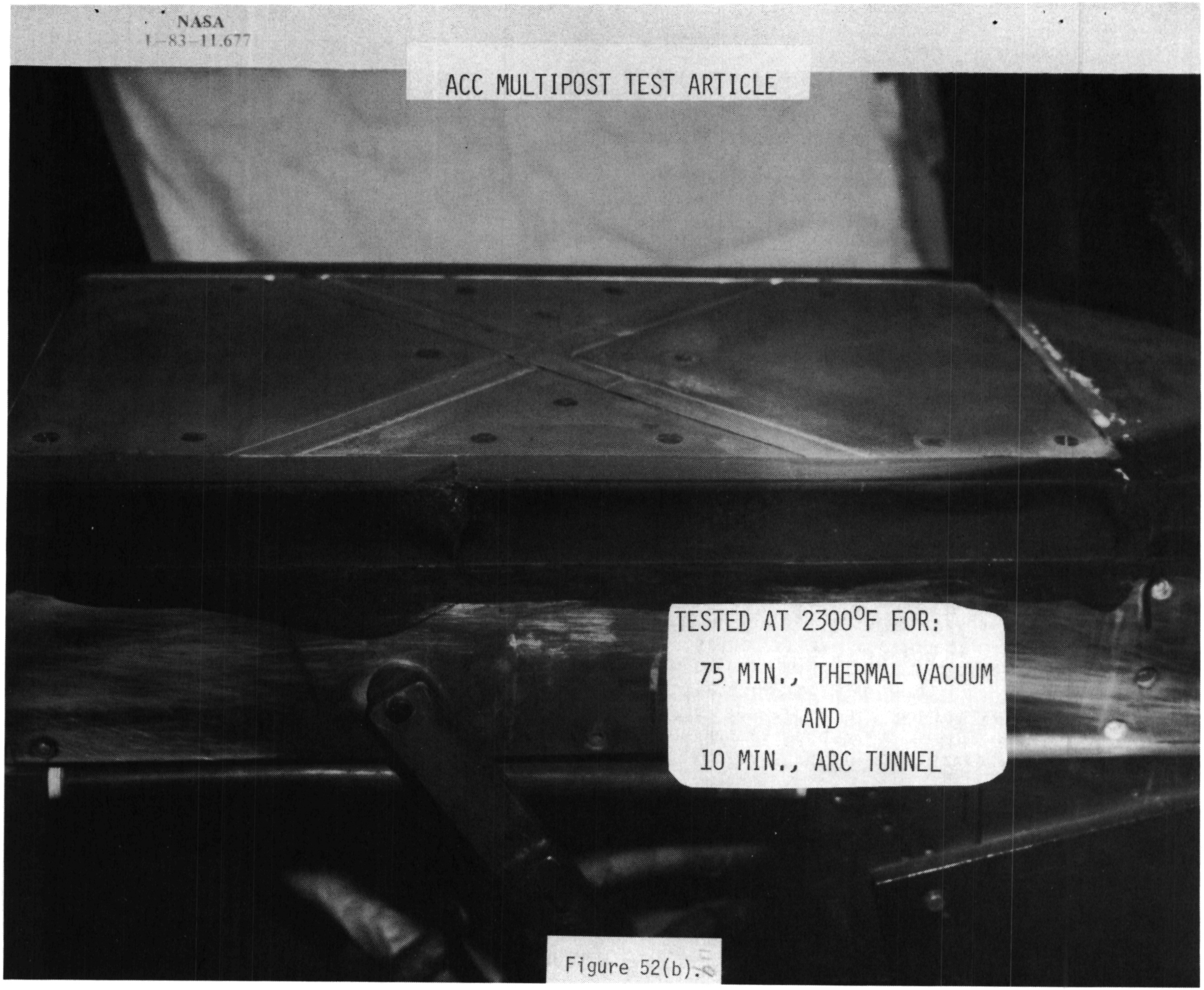
RTOP 506-53-33

Research Objective - One of the most promising durable TPS concepts for application to the highly heated areas of Future Space Transportation Systems is advanced carbon-carbon (ACC). This material is a derivative of the reinforced carbon-carbon (RCC) material which is being used successfully on the Shuttle nose-cap and wing leading-edges. The RCC material has been modified to improve strength and oxidation resistance and renamed ACC. The ACC TPS concept consists of large overlapping ACC panels (approximately 3 ft. x 3 ft.) mounted on post supports with packaged fibrous insulation between the ACC panels and the main vehicle structure. The objective of this research is to develop high temperature durable TPS systems.

Approach - The ACC test article is shown in figure 52(b). The test article is composed of four panel segments, representing the intersection of four ACC multipost concept panels. The overall size of the test article is 1 ft. x 2 ft. and the height can be adjusted to permit testing different TPS thicknesses and insulation packages. The test article has been delivered complete with ACC panels and seals, support posts, packaged insulation, simulated vehicle structure and appropriate thermocouple instrumentation. The test article has been tested in the radiant heating environments. It will be tested in an arc-tunnel environment in FY 84. Testing in these two environments should provide a good measure of the thermal efficiency of the heat shield and a comparison of the performance between the two environments should indicate whether hot gas flow through the panel joints is significant. Any weight change in the ACC panels due to high temperature exposure can also be determined.

Status/Plans - Testing of the ACC test article in the radiant heating has been completed. Testing in the arc-tunnel has begun with completion expected in mid-1984. The next step in this research is to improve the current panel design, to simplify manufacturing, and reduce costs while improving the thermal characteristics. This design effort will also develop lightweight, water resistant insulation packages. The testing that is required to further evaluate the ACC multipost TPS concept will be identified.

Figure 52(a).



ACC MULTIPOST TEST ARTICLE

TESTED AT 2300°F FOR:

75 MIN., THERMAL VACUUM
AND
10 MIN., ARC TUNNEL

Figure 52(b).

LIFTING SURFACE TEST APPARATUS

L. Roane Hunt
Aerothermal Loads Branch
Extension 3423

RTOP 506-51-23

Research Objective - The basic test apparatus used in the Langley 8' High Temperature tunnel has been a flat, wedge-shaped, panel holder where two-dimensional flow was assured by a leading edge normal to the tunnel flow and side fences to minimize cross-flow. This apparatus has been used successfully in numerous test programs for thermal protection system (TPS) evaluation and detailed flow studies. Two additional test apparatus have been developed to extend test capabilities to three-dimensional flow fields. The Curved Surface Test Apparatus (CSTA) represents the forward portion of a lifting body with very large pressure gradients of chine surfaces. The Lifting Surface Test Apparatus (LSTA) represents the tip portion of a swept wing-elevon configuration where natural cross flow can be produced. The LSTA will be especially useful in the extension of many previous tests with two-dimensional flow to include realistic cross-flow effects. Both the CSTA and LSTA will also be used as a test bed for TPS evaluations and detailed flow studies.

Approach - The primary design consideration for the LSTA was to provide a versatile apparatus to support a variety of test programs. The basic structure consists of a strongback to which the leading edge, elevon control surface, and tip are attached. Initially the LSTA will be covered with instrumented boilerplate outer moldline surfaces for basic aerothermal load definition studies, but these surfaces and the other components can be replaced with flightweight components. The potential versatility of the LSTA is also indicated by provisions for variation in wing pitch angle, leading edge sweep angle, and control surface deflection angle.

Status/Plans - The LSTA is being fabricated and delivery is scheduled to permit testing in the 8' HTT in July 1984. The aerodynamic pressure and heating-rate distributions on the apparatus produced by the three-dimensional flow field will be determined for future flow studies and TPS evaluation. During the initial test, special instrumentation in the wing-elevon cove will indicate the three-dimensional flow effects on the gas leakage past cove seals as an extension of previous studies using the two-dimensional panel holder.

Figure 53(a).

LIFTING SURFACE TEST APPARATUS

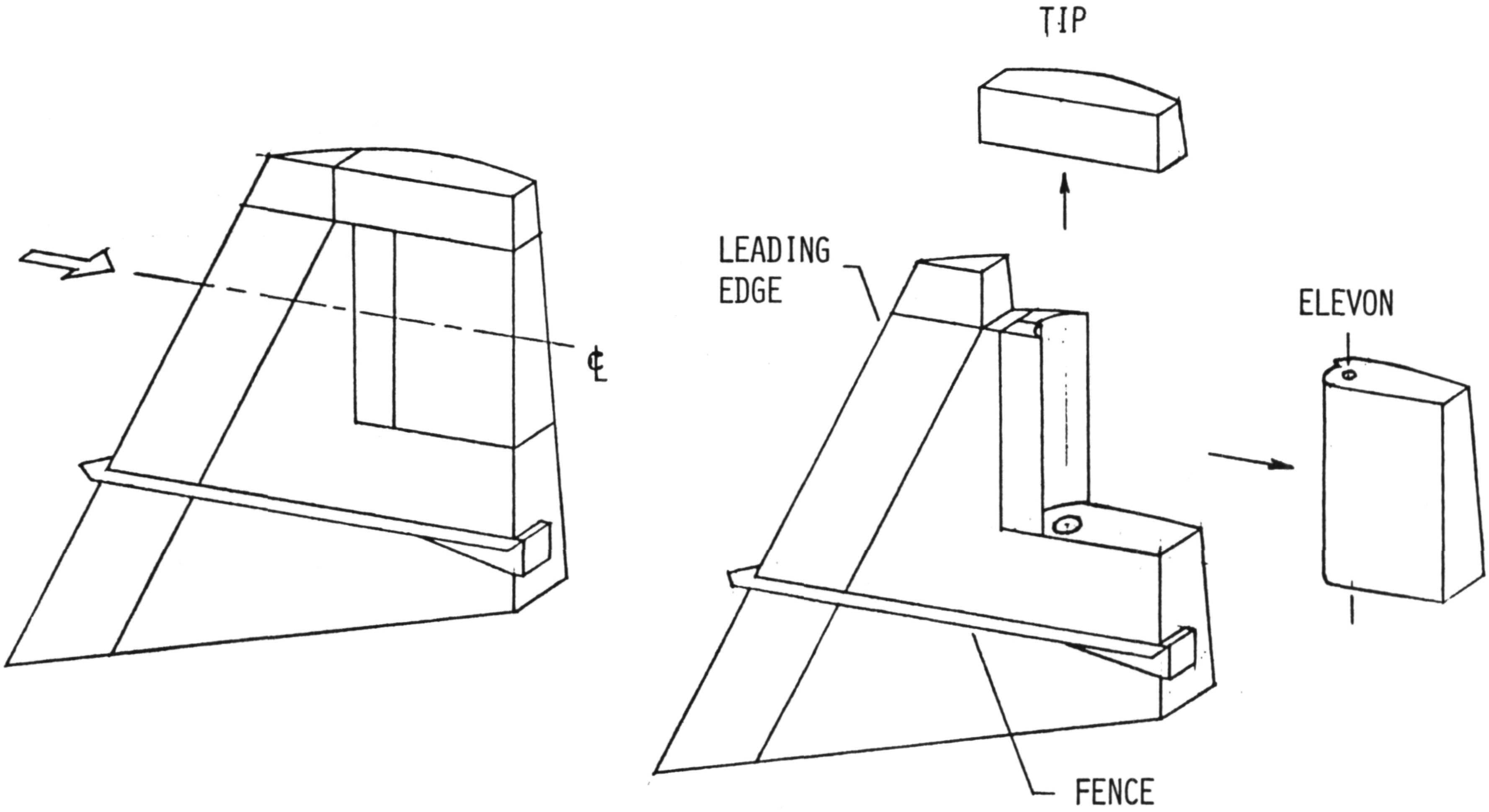


Figure 53(b).

CHINE GAP HEATING TEST

L. Roane Hunt
Aerothermal Loads Branch
Extension 3423

RTOP 506-51-23

Research Objective - The application of reusable surface insulation tiles on the Shuttle has introduced local flow disturbances associated with the gaps between tiles. The effects of these disturbances and the resulting penetration flow into the tile gaps has been studied extensively on flat surfaces. Important parameters including gap width and length and flow angularity have been identified, and the effects on localized and total heat loads have been evaluated. Similar studies are needed for curved surfaces where natural pressure gradients occur that would cause greater flow ingestion into the tile gaps and augment the aerothermal loads. For the Shuttle, many of the tile gaps are filled to circumvent this problem, but this practice costs in weight and labor. The actual aerothermal loads associated with tile gaps on the chine with high surface pressure gradients need to be defined to serve as a data base for future thermal protection system designs.

Approach - The Curved Surface Test Apparatus, CSTA, has been developed as a test bed for the Langley 8-Foot High Temperature Tunnel. The CSTA is representative of the forward portion of a lifting body and the complex, three-dimensional flow field around this body has been defined experimentally and analytically. An extensive array of simulated tiles has been designed to cover a large portion of the CSTA. Thermocouple instrumented tiles will be located in the chine region and will be adjacent to solid tiles instrumented with pressure orifices to determine the aerothermal effects in the tile gaps.

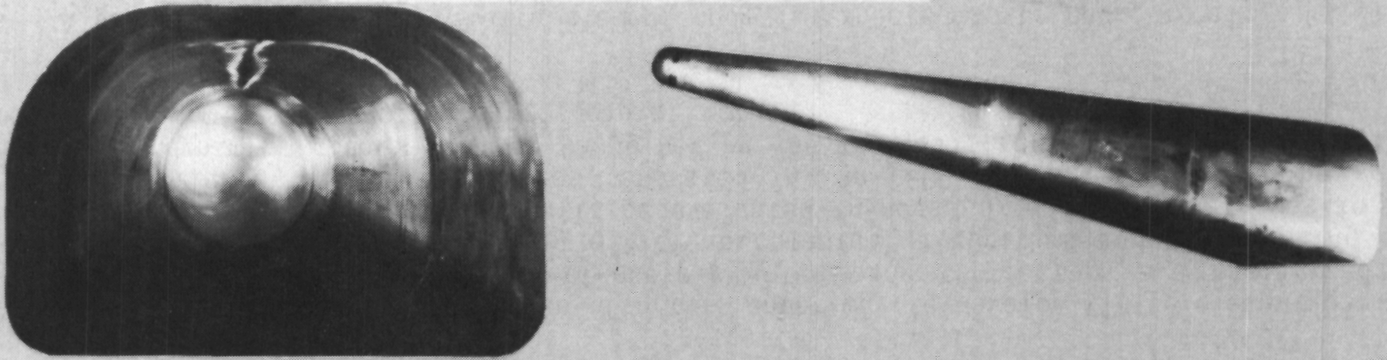
Status/Plans - The Chine Gap Heating Model fabrication was initiated in November, 1983, and the model competition is scheduled for June, 1984. Tests in the 8' HTT are planned for early 1985.

Figure 54(a).

NASA
L-83-11,522

CHINE GAP HEATING TEST CONFIGURATION

CURVED SURFACE TEST APPARATUS



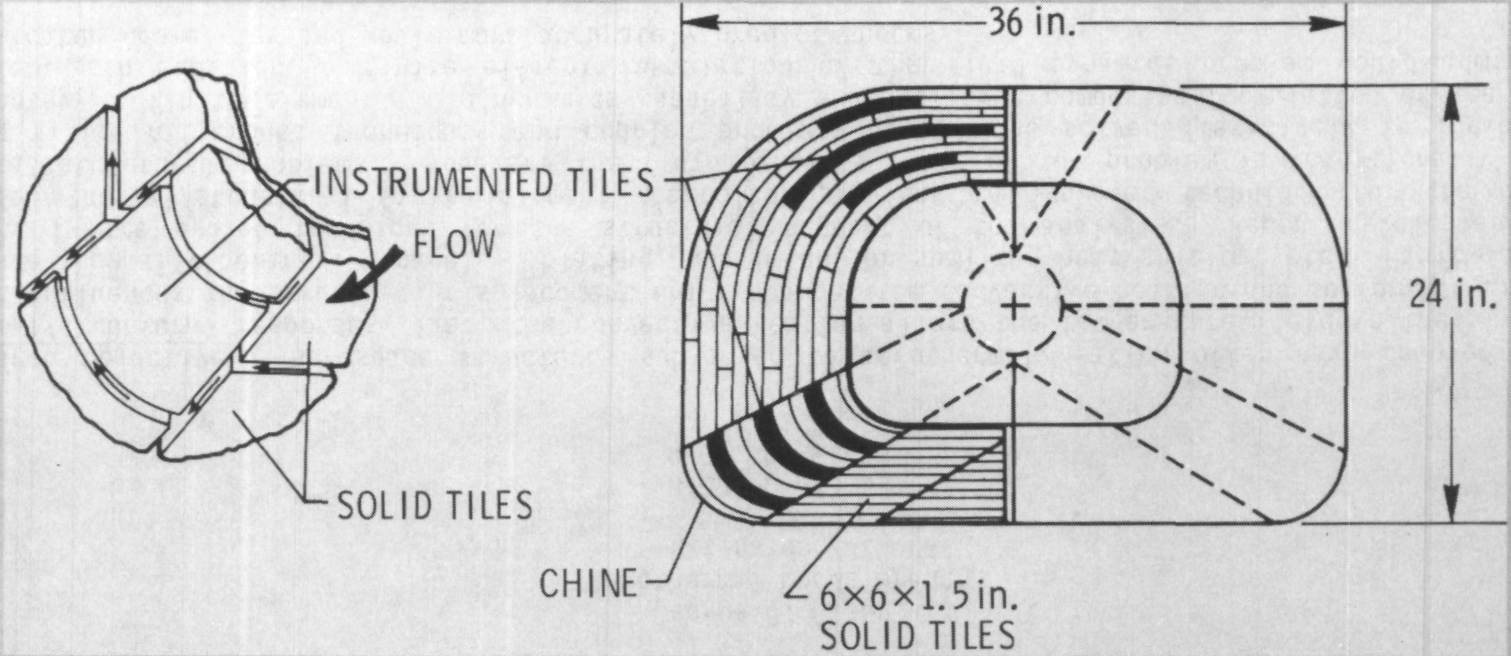


Figure 54(b).

INTEGRATED FLUID/THERMAL/STRUCTURAL ANALYSIS OF STRUCTURES WITH COUPLED RESPONSES

George C. Olsen
Aerothermal Loads Branch
Extension 2325

RTOP 506-53-53
RTOP 506-51-23

Research Objective - Aerospace structures subjected to aerothermal heating often have coupled fluid/thermal/structural responses, i.e., the convective heating alters the temperature field in the structure which influences the structural displacement which changes the convective heating and so forth. Examples include thermally bowing TPS panels, ablating, subliming, or spalling heat shields, etc. Finite element theory is the proven technique for the structural segment of the analysis. Recent development of a unified thermal/structural finite element technology provides an improved technique for the coupled thermal/structural problems. However, the fluid dynamics facet of the problem is traditionally solved using finite difference techniques and coupled problems have to be solved iteratively in independent segments. A finite element fluid dynamics capability would allow a composite formulation of the entire problem. In addition, a finite element formulation of the fluid dynamics problem would admit more complicated geometries and would more accurately predict shocks.

Approach - A combined in-house and out-of-house effort is under way to develop finite element methodology for computational fluid dynamics. The out-of-house grantees and contractors are summarized on the attached figure. Efforts focus on developing efficient numerical algorithms and implementing them in generalized application codes. The results will be evaluated in-house by applying the codes to a broad range of problems with experimental data bases generated in the LaRC 8' HTT facility. The resulting finite element fluid dynamics code will then be joined by the thermal/structural methodology to produce an integrated fluid/thermal/structural analysis capability.

Status/Plans - A pilot two-dimensional finite element code is expected to be operational in FY 84. This code will be used to evaluate algorithms and for numerical experimentation. The pilot code will then be followed by a three-dimensional generalized application code utilizing the most efficient algorithms.

Figure 55(a).

DEVELOPMENT OF FINITE ELEMENT METHODOLOGY
FOR
COMPUTATIONAL FLUID DYNAMICS

OUT-OF-HOUSE PARTICIPANTS

- T. R. J. HUGHES - STANFORD - NONLINEAR ALGORITHMS
- A. J. BAKER - U. OF TENN. - 3D PARABOLIZED NAVIER STOKES (PNS), ALGORITHM
- K. MORGAN, D. C. ZIENKIEWICZ - U. OF WALES - ELEMENTS/ALGORITHMS
- E. A. THORNTON, P. DECHAUMPHAI - ODU - VECTOR CODING, APPLICATIONS, GRAPHICS
- L. SPRADLEY - LMSC - GIM CODE ON WING ELEVON COVE
- J. T. ODEN - U. OF TEXAS - ADAPTIVE GRIDS

Figure 55(b).

1x3 HIGH ENTHALPY AEROTHERMAL TUNNEL

Randolph B. Heard
Aerothermal Loads Branch
Extension 3158

Objective - The 1x3 High Enthalpy Aerothermal Tunnel was designed to permit testing of advanced thermal protection systems. Models up to 2 feet by 3 feet can be subjected to realistic combinations of aerodynamic heating and pressure loading for test times up to 30 minutes. The energy level of the test gas (ranging from 1000 to 4400 Btu/lb) is generated by burning methane in air and/or oxygen under pressure. The facility is also of interest, because of its high energy level flow, for experimental aerothermodynamics research. A first step in evaluating the potential for such research is to obtain a good flow survey.

Approach - The tunnel has been reactivated to an operational status using a solid heat sink nickel liner while a new water-cooled liner was being fabricated. The new water cooled liner has been installed and is being prepared for its initial test phase. The original survey panel will be refurbished and the tunnel will be surveyed starting with energy levels obtained by combustion of methane and air and moving up to the maximum conditions obtained by burning methane and oxygen.

Status/Plans - The tunnel is presently having the water cooled components cleaned and checked for leaks. The tunnel should be reassembled in early CY 1984. Testing should begin mid CY 1984.

Figure 56(a).

1 x 3 HIGH ENTHALPY AEROTHERMAL TUNNEL

M = 3.5 TO 4.5
P_T = 0.276 TO 2.07 MPa
T_t = 1667 TO 3333 K
H_T = 9.66 TO 43.2 MJ/m^2
q = 7.85 TO 79.0 kPa
R_e/m = 0.82 × 10^6/m TO 4.53 × 10^6/m
ALTITUDE = 15.2 TO 35.1 km
MAXIMUM RUNNING TIME = 30 min

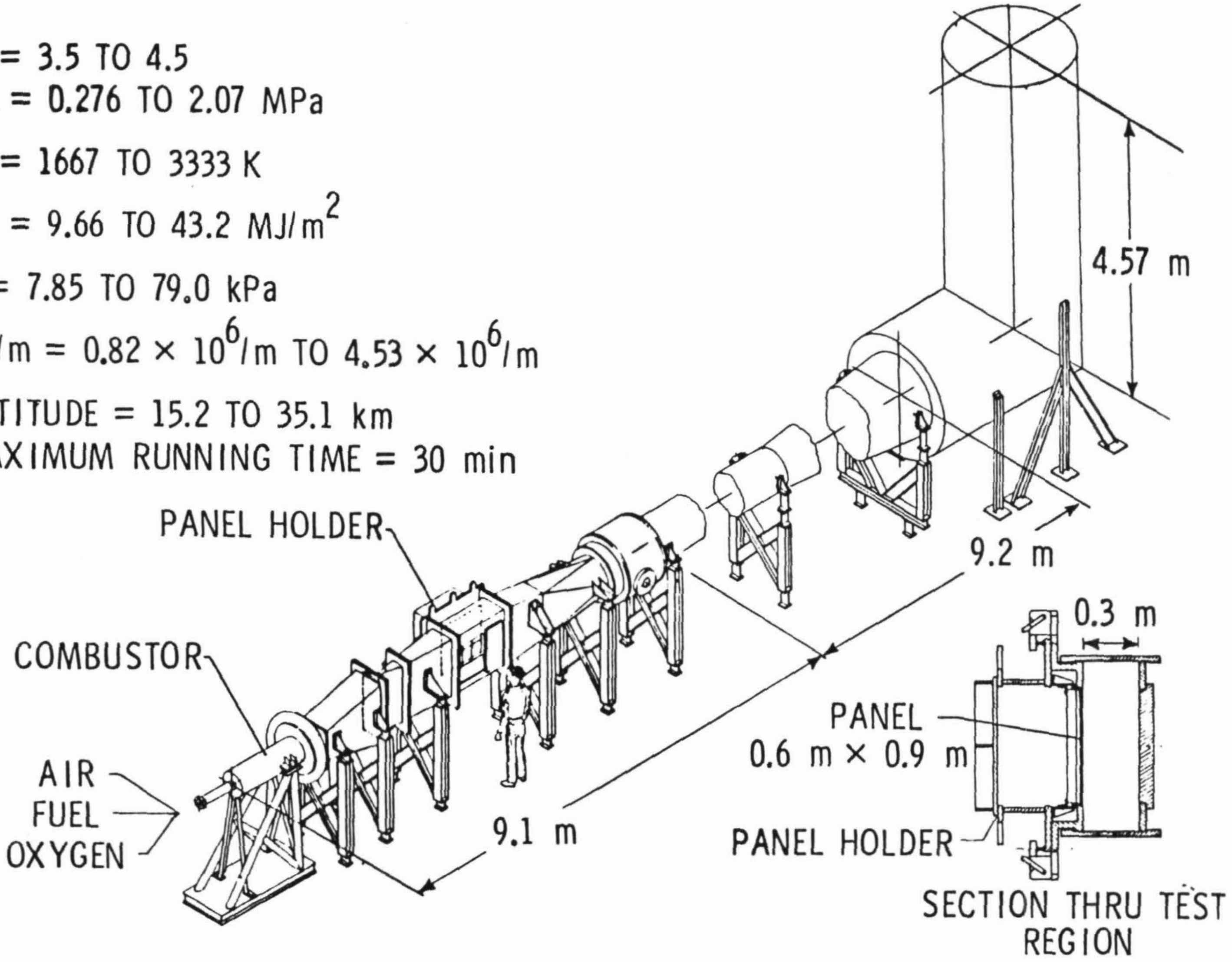


Figure 56(b).

DYNAMIC BEHAVIOR OF STATICALLY-UNSTABLE FSW AIRCRAFT

Carol Wieseman
Multidisciplinary Analysis and Optimization Branch
Extension 3323

RTOP 505-33-43

Research Objective - Recently, the stability and control characteristics of forward-swept-wing (FSW) aircraft have been shown to be significantly different if structural dynamics are included in the analysis. Preliminary studies under grant to Purdue University have shown that a "body-freedom" instability can occur on FSW aircraft that is more critical than the traditional divergence instability. This instability is a coupling between the aircraft short period mode and the first wing bending mode. The purpose of the present study is to analyze a more realistic model of a FSW aircraft to validate the preliminary studies performed under grant.

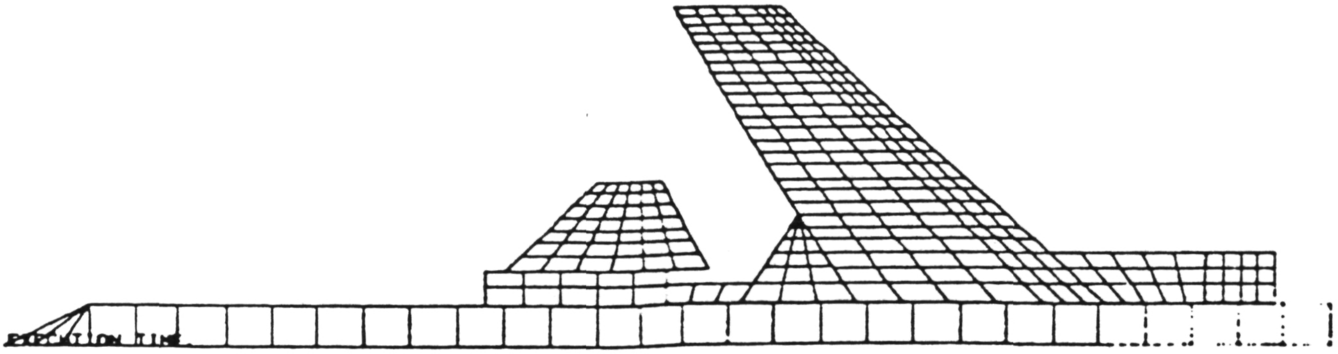
Approach - The aircraft that will be analyzed is the X-29A flight demonstrator. A modal representation of the aircraft will be employed to study the dynamic aeroelastic characteristics of this vehicle. Unsteady aerodynamic effects will be modelled using a Doublet Lattice program. The panelling arrangement is shown on the accompanying figure. Since the X-29A is highly unstable, the flight control system will be included in the analysis. The sensitivity to variations in the control system will be examined. Both classical control theory and modern control theory methods will be used.

Status/Plans - The aerodynamic representation of the aircraft is being checked against wind-tunnel data. After the aerodynamic model has been found to be satisfactory, the unsteady aerodynamic forces for a sufficient number of flexible modes will be computed. The coefficients of the equations of motion will be computed and linear analyses will be performed.

Figure 57(a).

DYNAMIC BEHAVIOR OF STATICALLY UNSTABLE FORWARD-SWEPT-WING AIRCRAFT

AERODYNAMIC MODEL



VELOCITY ROOT LOCUS
SAS-ON

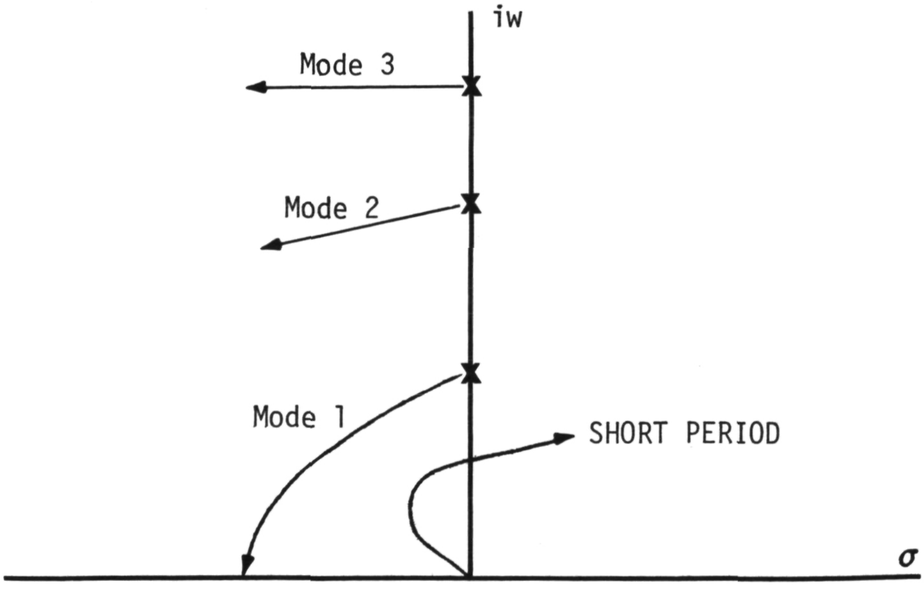


Figure 57(b).

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ANALYTICAL SENSITIVITY DERIVATIVES FOR AERODYNAMIC PERFORMANCE

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Multidisciplinary Analysis and Optimization Branch
Extension 3451

RTOP 505-33-53

Research Objective - The objective of this long range research effort is to develop and validate analytical methods to compute derivatives of aerodynamic performance quantities such as drag, lift, moment and pressure coefficients with respect to configuration variables such as aspect ratio, sweep angle, taper, airfoil shape, etc., throughout the range of subsonic, transonic, and supersonic speeds for both steady and unsteady conditions. This capability will be incorporated in the MAOB system for multidisciplinary optimization of aircraft using multilevel decomposition techniques.

Approach - Near term efforts will focus on steady subsonic aerodynamics. In a joint effort with Aeronautics Directorate researchers, a previous research program which produced derivatives for steady subsonic flow with respect to airfoil shape will be extended. The initial step will be to incorporate planform shape parameters as independent variables. A computer program developed under contract by McDonnell-Douglas Corporation will form the basis for the initial work.

Status/Plans - Discussions with Aeronautics Directorate personnel indicated a strong interest in cooperating on this program. Work performed under contract by McDonnell-Douglas has been reviewed and tentative plans are for an extension of the work to include aspect ratio, sweep angle, and taper as design (independent) variables. A companion in-house effort will be initiated upon identification of an aerodynamics research specialist to work with MAOB.

Figure 58.

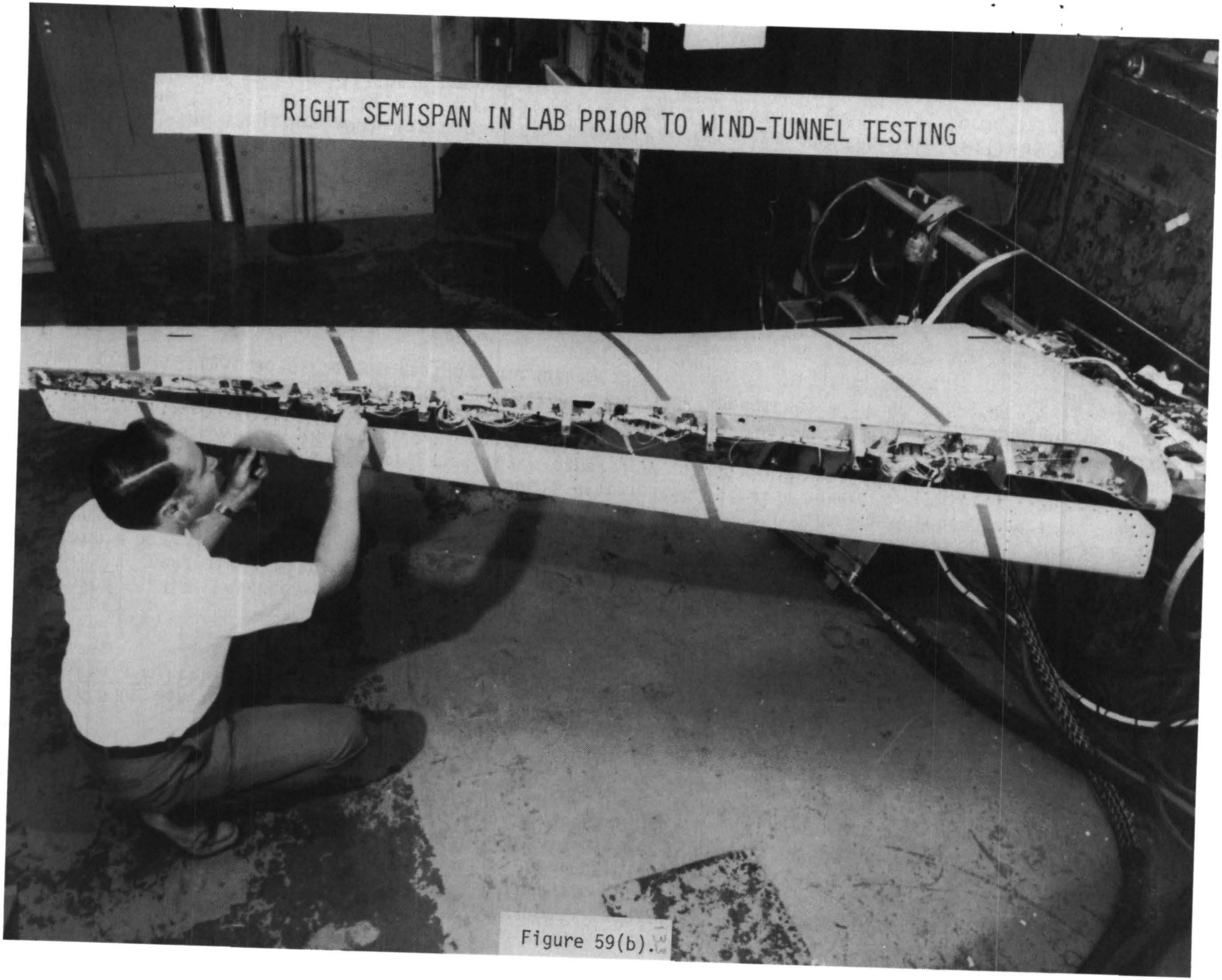
ARW-2 PLANS

Harold N. Murrow
Multidisciplinary Analysis and Optimization Branch
Extension 3527

RTOP 505-33-43

The DAST ARW-2 hardware is essentially complete. The accompanying photograph shows the right semispan being prepared for a wind-tunnel test to measure unsteady pressure distributions due to control surface oscillations. As a result of the loss of the ARW-1R vehicle, the program is being reviewed for possible adjustments to provide additional assurance of success in the flight test series. Possible program modifications include fabrication of an uninstrumented rigid ARW-2 for use in flight qualification of the test vehicle and systems. As a result of this review, a plan will be formulated for proceeding into the flight test phase, and implementation will begin with the first flight expected in about 24 months.

Figure 59(a).



RIGHT SEMISPAN IN LAB PRIOR TO WIND-TUNNEL TESTING

Figure 59(b).

STUDY FOR OPTIMIZATION OF A TRANSPORT AIRCRAFT WING FOR MAXIMUM FUEL EFFICIENCY

Gary L. Giles
Multidisciplinary Analysis and Optimization Branch
Extension 3860

RTOP 505-33-53

Research Objective - The objective of this study is to demonstrate the use of formal optimization procedures in a multilevel approach on an analytical model that is being studied in industry using traditional methods.

Approach - The Lockheed-California Company is using their traditional methods involving parametric studies to generate a wing design for an L-1011 derivative aircraft, shown in figure 60(b), which will perform a specified mission with minimum block fuel. Lockheed is under contract to provide sufficient design data from their studies to allow NASA personnel to study the same configuration at the same level of detail. NASA is applying formal optimization in the process which has been decomposed into levels of (1-TOP) overall aircraft performance, (2-MIDDLE) distribution of wing cover skin material, and (3-BOTTOM) cross-sectional dimensions of stiffened cover panels, as shown in figure 60(c). Communication of data between these levels in the multilevel approach is used to achieve the desired optimum performance goal at the top level while satisfying the more detailed design constraints at the middle and bottom levels. Results and experiences obtained from the Lockheed and NASA approaches will be compared to assess relative merits of the two different design methodologies.

Status/Plans - A computer program, FLOPS, has been developed for optimization of overall aircraft mission performance at the top level. This program has capability to specify a general mission and has been modified to operate in the multilevel system. A program, OPCOM, has been developed for stiffened panel optimization at the bottom level and has been converted into an EAL processor for use in the multilevel system. Results from FLOPS and OPCOM compare favorably with results produced by corresponding Lockheed methods. The Lockheed finite element structural model shown in figure 56(d) has been converted for use in the EAL analysis system. The development of remaining NASA procedures for the middle level is nearing completion. At that time the middle and bottom levels will be integrated to provide capability to optimize a wing structure with fixed planform geometry. Finally, the top level will be integrated to complete the three-level system. The multilevel system will then be used to perform design studies and NASA and Lockheed results will be compared.

Figure 60(a).

ADVANCED TRANSPORT CONFIGURATION

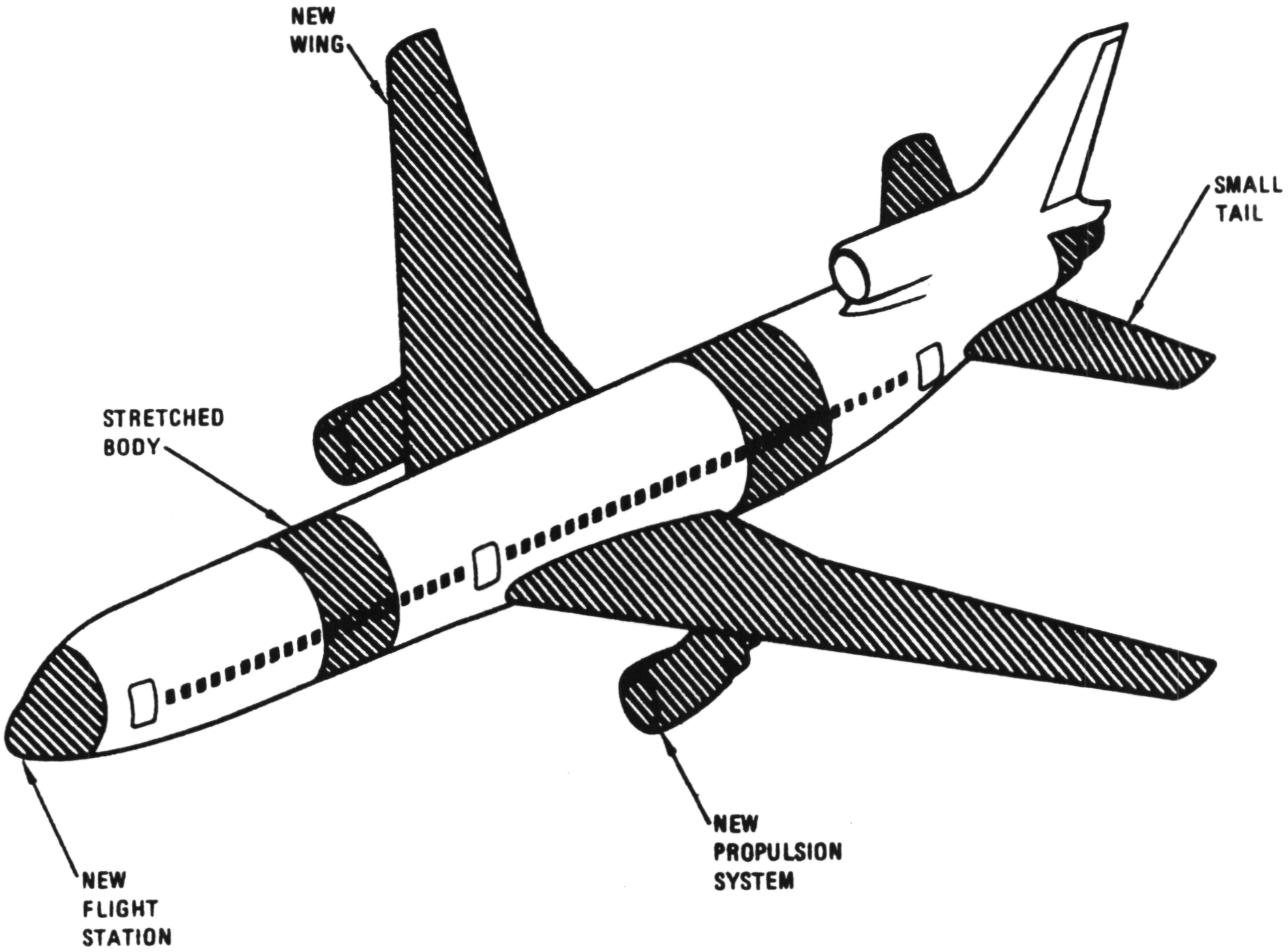
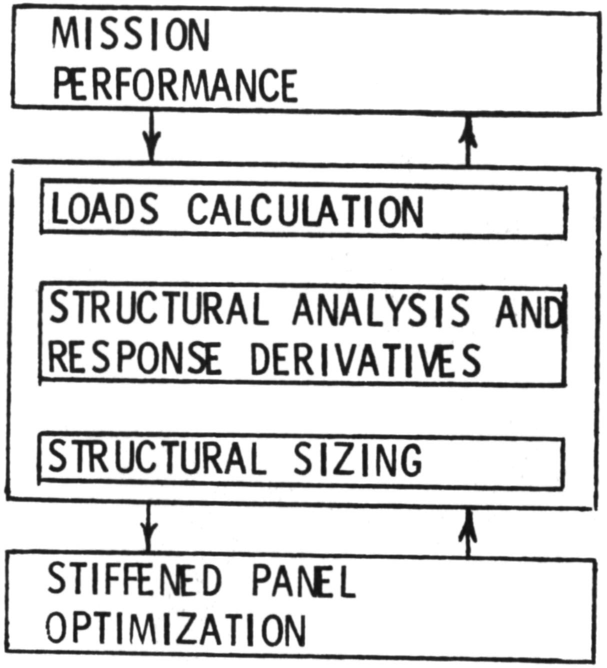


Figure 60(b).

MULTILEVEL OPTIMIZATION IMPLEMENTATION FOR L-1011 DERIVATIVE WING



LEVEL		STATUS
TOP	MISSION PERFORMANCE	STANDALONE PROGRAM COMPLETE
MIDDLE	LOADS CALCULATION STRUCTURAL ANALYSIS AND RESPONSE DERIVATIVES STRUCTURAL SIZING	EAL PROCESSORS AND RUNSTREAMS UNDER DEVELOPMENT
BOTTOM	STIFFENED PANEL OPTIMIZATION	EAL PROCESSOR COMPLETE

MILESTONES

1. INTEGRATE MIDDLE AND BOTTOM LEVELS
2. ADD TOP LEVEL
3. COMPARE RESULTS WITH LOCKHEED TO VERIFY THE METHOD

Figure 60(c).

FINITE ELEMENT STRUCTURAL MODEL
FOR MULTILEVEL OPTIMIZATION STUDY

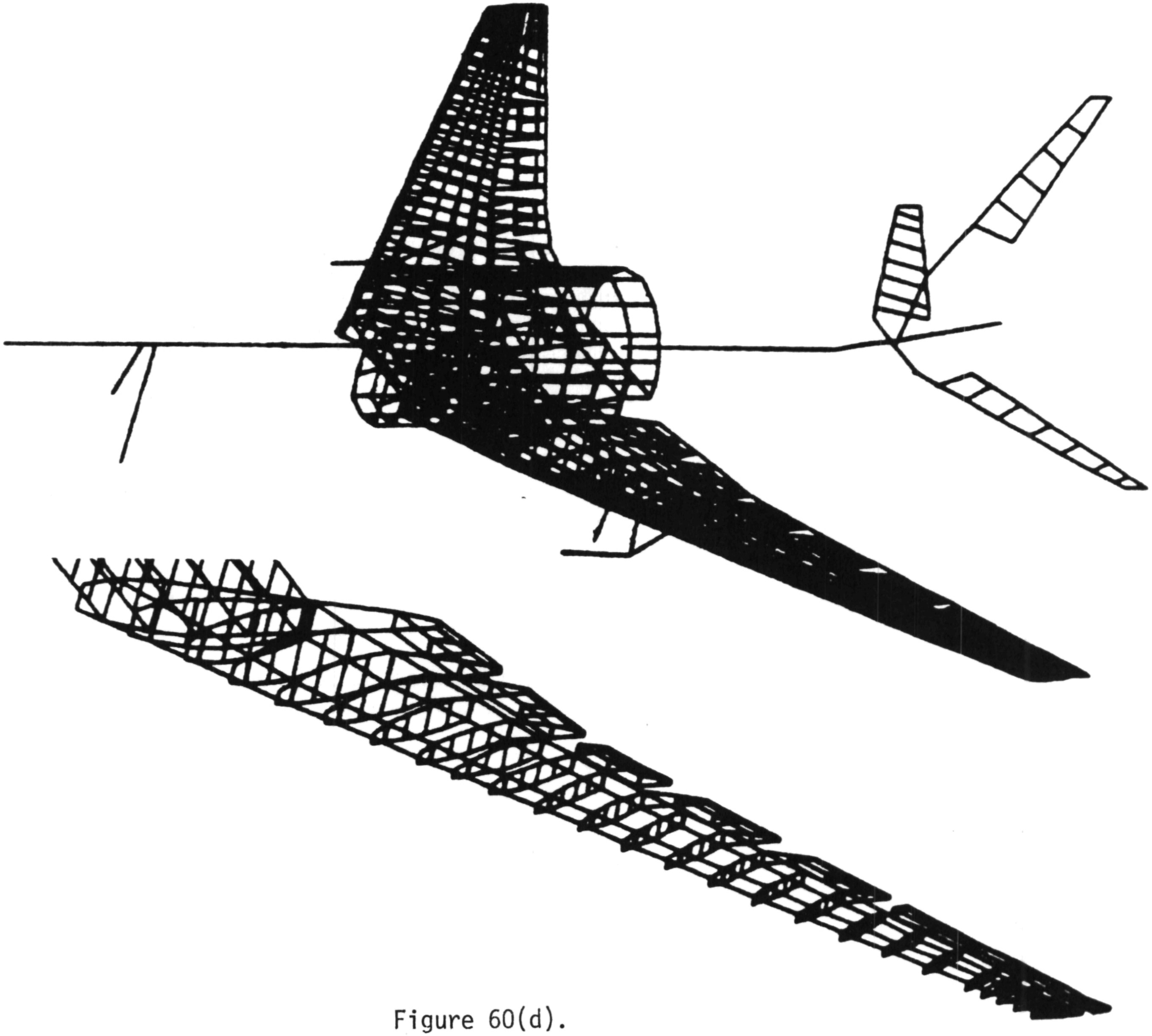


Figure 60(d).

ADS - A NEW GENERAL-PURPOSE OPTIMIZATION PROGRAM

James L. Rogers, Jr. and Jaroslaw Sobieski
Multidisciplinary Analysis and Optimization Branch
Extension 3451

RTOP 505-33-53

Research Objective - The objective of this research is to develop a general-purpose optimization program containing a variety of modern algorithms for use in structural synthesis.

Approach - Collect the most widely used state-of-the-art algorithms for structural synthesis, and incorporate them into a single computer program. Make the program flexible by dividing the design task into three basic levels - strategy, optimizer, and one-dimensional search - with each level having several options. Make the program easy to use by providing defaults for all the internal program parameters and giving the user a simple means to override these parameters.

Status/Plans - The ADS (Automated Design Synthesis) program is being developed by Dr. Gary Vanderplaats under a grant with The Naval Postgraduate School. The first release of ADS was made available to LaRC in March 1983. The release contained nine strategies, ten optimizers, and ten search algorithms. It will execute on the CDC CYBER mainframe computer, the PRIME minicomputer, and the DEC VAX minicomputer. Its availability was made known to potential LaRC users so they could try ADS and provide feedback on problems and deficiencies. Very few problems have been reported thus far. A new release of ADS is scheduled for November 1983. It is planned to make this release available to the public through COSMIC as well as the LaRC user community.

Figure 61(a).

NEW OPTIMIZATION PROGRAM
(AUTOMATED DESIGN SYNTHESIS - ADS)

	OPTIMIZER									
STRATEGY	0	1	2	3	4	5	6	7	8	9
0	X	X	X	X	X	X	X	X	X	X
1	0	0	X	0	X	X	X	0	X	0
⋮										
7	0	X	0	X	0	0	0	0	0	0
8	0	X	0	X	0	0	0	0	0	0
SEARCH										
1	X	0	0	0	0	0	X	0	0	0
2	X	0	X	0	X	X	X	0	X	X
⋮										
9	X	X	0	X	0	0	0	X	0	0
10	X	X	0	X	0	0	0	X	0	0

- OVER 150 POSSIBLE COMBINATIONS OF STRATEGIES, OPTIMIZERS, AND SEARCH ALGORITHMS

Figure 61(b).

AN EXPERT SYSTEM TO CHOOSE THE BEST COMBINATION OF OPTIONS IN ADS

James L. Rogers, Jr.
Multidisciplinary Analysis and Optimization Branch
Extension 3451

RTOP 505-33-53

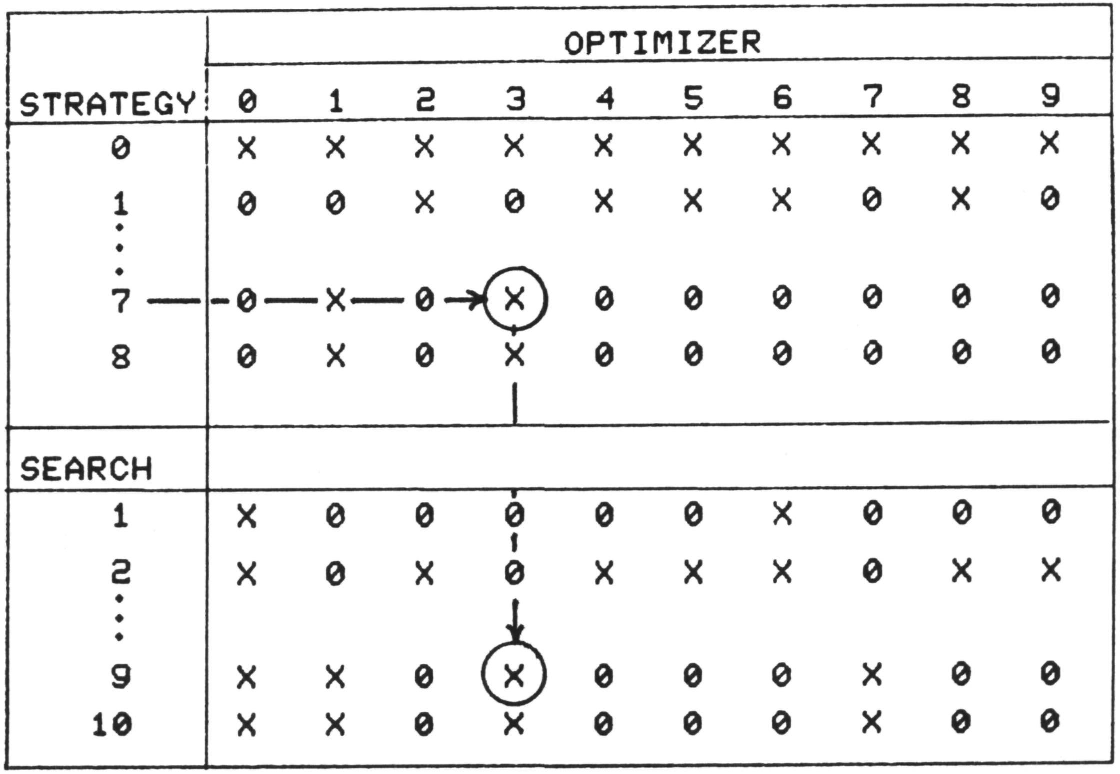
Research Objective - The objective of this research is to develop an expert system to aid an engineer in selecting the best combination of options from the ADS (Automated Design Synthesis) computer program.

Approach - The approach is divided into three stages all of which are to be done in-house. In the feasibility stage, several artificial intelligence tools, such as LISP and PROLOG, will be used on a subset of options from ADS to determine which is the best tool for this application. Also a questionnaire will be developed and sent out to known optimization experts to acquire knowledge about how they would make their decisions in choosing parameter in ADS. In the next stage, prototype development, the acquired knowledge will be coded into a rule based expert system. This system will be able to explain why certain questions are asked and how conclusions are reached. This system will be documented and sent to a few select users for test and evaluation. In the third stage, a delivery system will be developed and documented based on the feedback from the users of the prototype system. This delivery system will be distributed to the public through COSMIC.

Status/Plans - Currently testing is being done applying LISP, PROLOG, and PIL (PROLOG in LISP) to a small set of rules about ADS which were acquired from two local optimization experts. A questionnaire is being developed for delivery to other experts. After receiving responses to the questionnaire, the rules will be expanded and further testing will be done on the tools.

Figure 62(a).

AN EXPERT SYSTEM TO CHOOSE THE BEST POSSIBLE COMBINATION OF OPTIONS IN ADS



	OPTIMIZER									
STRATEGY	0	1	2	3	4	5	6	7	8	9
0	X	X	X	X	X	X	X	X	X	X
1	0	0	X	0	X	X	X	0	X	0
⋮										
7	0	X	0	X	0	0	0	0	0	0
8	0	X	0	X	0	0	0	0	0	0
SEARCH										
1	X	0	0	0	0	0	X	0	0	0
2	X	0	X	0	X	X	X	0	X	X
⋮										
9	X	X	0	X	0	0	0	X	0	0
10	X	X	0	X	0	0	0	X	0	0

- OVER 150 POSSIBLE COMBINATIONS OF STRATEGIES, OPTIMIZERS, AND SEARCH ALGORITHMS IN A MAJOR NEW OPTIMIZATION PROGRAM
- EXPERT SYSTEM TO BE DEVELOPED TO GUIDE USERS

Figure 62(b).

A GENERALIZED N-LEVEL STRUCTURAL OPTIMIZATION

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Extension 3451

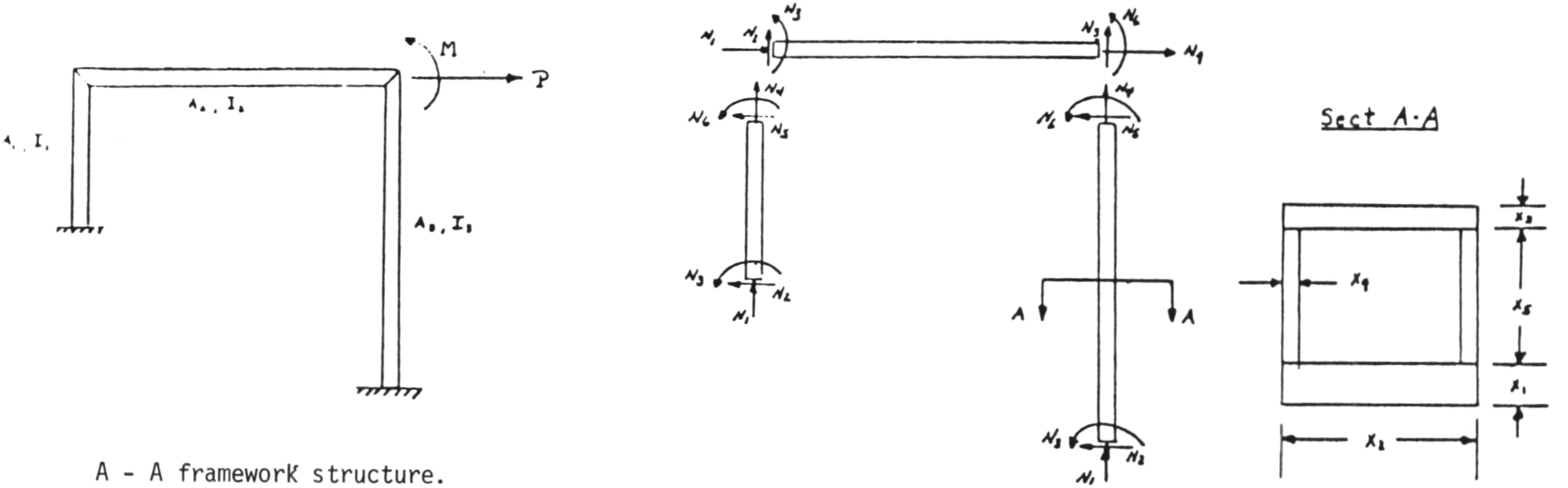
RTOP 505-33-53

Research Objective - The objective of this research is to validate by numerical examples the theory of optimization by decomposition in application to complex systems that can be partitioned in a number of subsystems. Example of such a system is a redundant structure, a framework shown in the figure, that decomposes into substructures, the individual box beams in the example, and each substructure decomposes into its component part, as the stiffened panels in the example.

Approach - The structure is initialized and analyzed by means of a standard substructuring analysis. Then, each subsystem at the lower level (an individual stiffened panel) is optimized in detail, and the sensitivity derivatives of that optimum are calculated with respect to the design variables of its parent subsystem (the beam the panel is a part of). The next step is to optimize each subsystem at the next higher level (each beam) using a linear extrapolation based on the optimum sensitivity derivatives to account on the influence of the design variables of that level on the optima previously obtained at the level below (the panels). The optimum generated in this manner is analyzed for sensitivity with respect to the design variables of the level above which, in the example, is the complete framework. As the last step in the iteration, the complete system (a framework in the example) is optimized taking into account the effect of its design variables on the subsystems below (beams and panels) by means of linear extrapolation based on the optimum sensitivity derivatives brought up from these subsystems. The iteration involving analysis of the new system and optimizations through all levels from the bottom up continues until the objective function (minimum weight in the example) is attained and the constraints at all levels are satisfied.

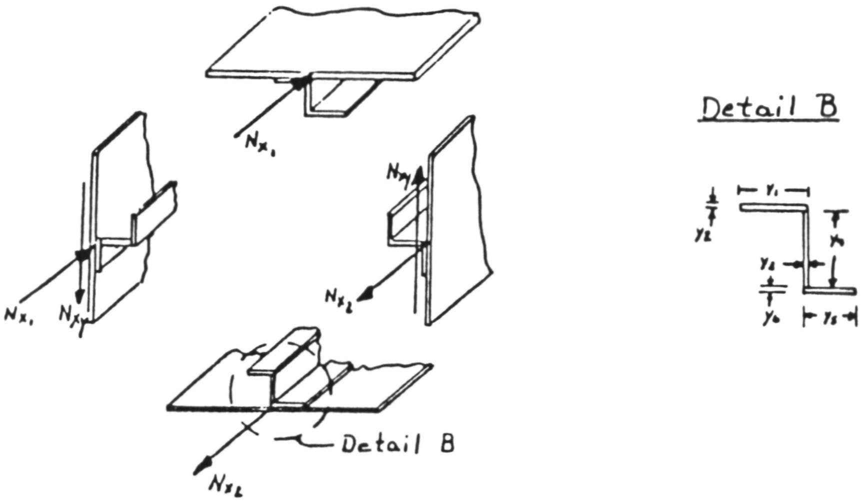
Status/Plans - A system of computer programs has been assembled to execute the above procedure for the framework example. The system is operational and is now generating results which are expected to be reported as a work-in-progress paper at the AIAA SDM Conference in May 1984.

Figure 63(a).



A - A framework structure.

B - A framework decomposed into beam substructures. Each beam has a box cross-section (Sect. A-A) and is being loaded by the end forces which are the framework internal forces.



C - Box beam decomposed into stiffened panels. Each panel is being loaded by the distributed edge forces.

Figure 63(b).

OPTIMIZATION TECHNIQUES APPLIED TO HELICOPTER ROTOR DESIGN

Joanne L. Walsh
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Extension 3834

RTOP 532-06-13

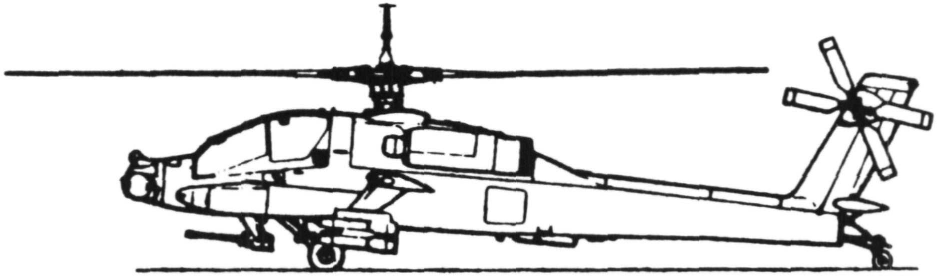
Research Objective - The objective of the research is to apply formal mathematical optimization procedures to obtain a rotor aerodynamic shape design to minimize hover power while not degrading forward flight performance.

Approach - Couple hover analysis (HOVT), forward flight performance (C81), and blade planform generation programs with an optimization program (CONMIN). Use the resulting system to obtain the blade planform, twist distribution, and solidity which minimize the power required for hover while providing a specified design speed with the power available, satisfying limits on drag and moment coefficients, and meeting a specified load factor at a speed less than the design speed. Airfoils and their radial distribution are specified by the user.

Status/Plans - The coupled procedure has been developed and is being checked out by comparisons with rotor designs obtained using the conventional parametric approach. The new approach obtains a rotor design in one day as opposed to 4-6 weeks using the old approach. Plans are to eventually extend this project to include dynamic and structural design constraints for minimum rotor-induced vibration.

Figure 64(a).

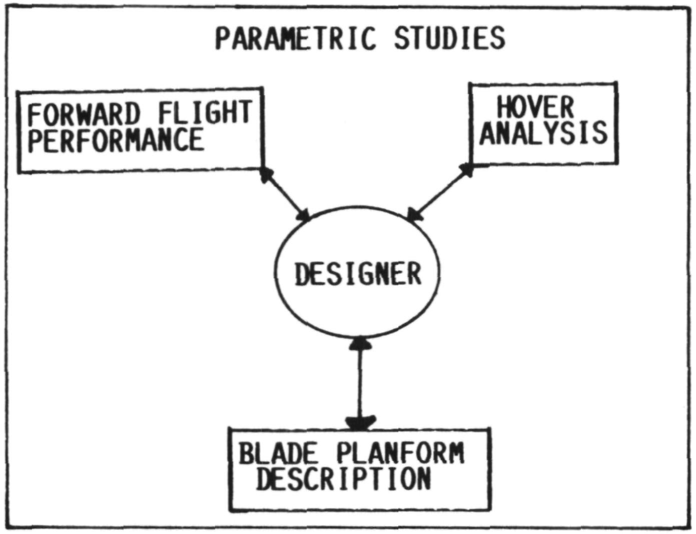
OPTIMIZATION METHOD DEVELOPED TO OPTIMIZE ROTOR BLADES FOR MINIMUM POWER.



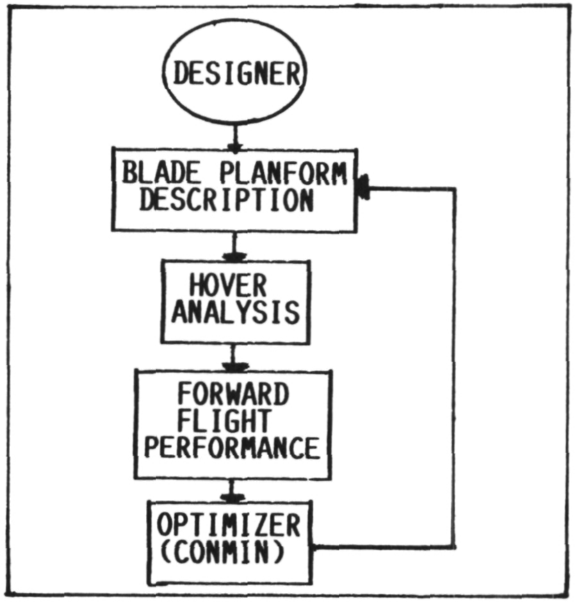
PROBLEM: MINIMIZE POWER REQUIRED TO HOVER

DESIGN VARIABLES: TWIST, TAPER, SOLIDITY

CONSTRAINTS: POWER REQUIRED AT A GIVEN VELOCITY, LOAD FACTOR,
LIMITS ON DRAG AND MOMENT COEFFICIENTS



OLD WAY: 4 TO 6 WEEKS



NEW WAY: 1 DAY

Figure 64(b).

DEVELOPMENT AND APPLICATION OF XTRAN3S

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Unsteady Aerodynamics Branch
Extension 4236

RTOP 505-33-43

Research Objective - The objective of this research is to provide a viable computational method for analyzing the transonic flutter characteristics of isolated wings.

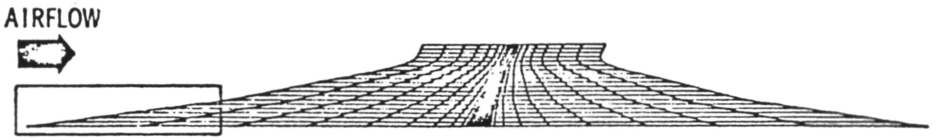
Approach - The unsteady transonic small perturbation equation is solved by a finite difference technique. The coupled aerodynamic and aeroelastic equations are numerically solved simultaneously in time such that complete aeroelastic transients are generated to determine the flutter characteristics. The program is called XTRAN3S and was developed by Boeing under Air Force contract. It has been implemented at LaRC on the CYBER 203 supercomputer. It is currently being applied, developed, and evaluated by applying to sample cases and comparing with other methods and experiment. The figure shows a sketch of the original grid and a modified grid recently developed at LaRC. The modified grid significantly alleviates a numerical stability problem that precluded the application of XTRAN3S to wings of significant sweep and taper.

Plans - Applications and development are continuing. Applications include the DAST ARW-2 semispan wing and a clipped delta wing tested in the LaRC TDT. Cooperative efforts with industry and the Air Force are underway. Further development of the numerical algorithm and possible boundary layer additions are planned.

Figure 65(a).

XTRAN3S GRID TRANSFORMATION MODIFIED TO ALLEVIATE INSTABILITY

ORIGINAL GRID



MODIFIED GRID

MODIFIED GRID

NEAR WING

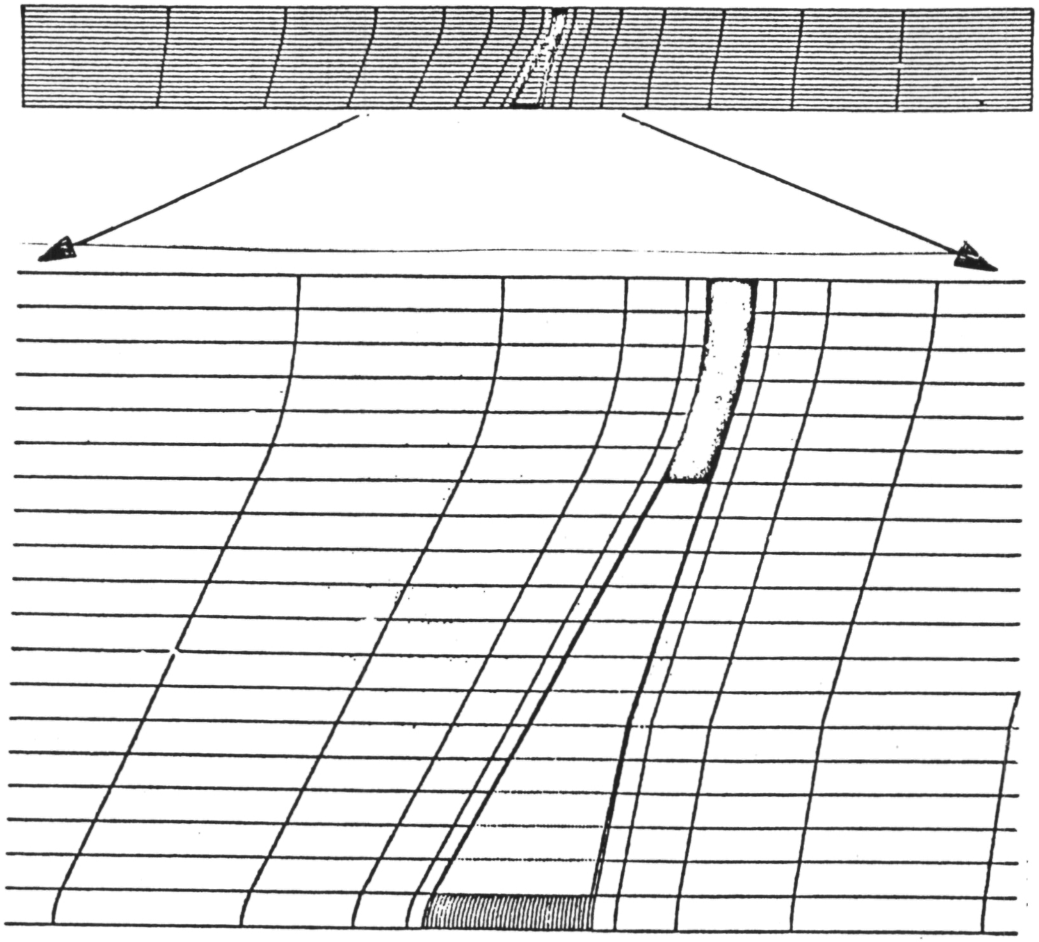


Figure 65(b).

UNSTEADY FULL POTENTIAL CODE FOR LOADS PREDICTIONS AND AEROELASTIC ANALYSIS

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Unsteady Aerodynamics Branch
Extension 4236

RTOP 505-33-43

Research Objective - Currently, unsteady aerodynamic loads for transonic aeroelastic analysis are obtained primarily by solving the transonic small disturbance (TSD) equation. Such analysis is limited because TSD theory fails in the region of blunt leading edges and is applicable only to thin bodies at small angles of attack, undergoing small amplitude unsteady motions. Thus, the objective of this research is to enhance our ability to perform aeroelastic analysis by developing a more accurate method for predicting unsteady aerodynamic loads.

Approach - The objective will be accomplished by using finite difference methods to solve the unsteady full potential equation in conservation form. Since the full potential approach does not have the above limitations, it is a significant improvement upon TSD methods. A monotone differencing method is used to solve the flow equations. This method does not allow nonphysical expansion shock waves to be computed as part of the numerical solution and is more efficient than conventional differencing techniques. The method has been tested on one-dimensional steady flow problems, and using Cartesian and body-fitted grids, on steady flows past airfoils. Nonreflecting far-field boundary conditions have also been developed.

Future Plans - Methods for analyzing unsteady flow problems are now being developed. The structural equations will be combined with the flow equations to allow aeroelastic effects to be included in the calculations. This will results in a more accurate (when compared with methods that use TSD aerodynamics) tool for aeroelastic analysis.

Figure 66.

EFFECTS OF AIRFOIL SHAPE, THICKNESS, ANGLE OF ATTACK, AND CAMBER ON TRANSONIC UNSTEADY AIRLOADS

John T. Batina
Unsteady Aerodynamics Branch
Extension 4236

505-33-43

Research Objective - The objective of this study is to investigate the effects of airfoil shape, thickness, angle of attack, and camber on transonic unsteady airloads as calculated by a finite-difference computational algorithm.

Approach - The two-dimensional, finite difference code XTRAN2L is used to determine the aerodynamic forces. This code provides a time-marching solution to the nonlinear, small-disturbance equation for transonic flow. The forces resulting from a pulse disturbance are Fourier transformed to obtain the forces for harmonic motion at all frequencies of interest. This technique will be used to examine the airfoil pressure distributions, shock locations, and unsteady aerodynamic forces for airfoils of various shapes and thickness/chord ratios. Shape effects will be investigated by comparing results for airfoils of the same thickness, computed at identical Mach numbers. Thickness effects will be investigated by comparing results for airfoils of the same shape but different thickness/chord ratio, computed at transonically scaled Mach numbers. Shape and thickness results will be obtained at both zero and non-zero mean angle of attack. Camber effects will be investigated by adding a simple, parabolic camber distribution to the airfoil thickness distribution.

Future Plans - The unsteady airloads and pressure distributions for three 10% thickness/chord ratio airfoils: NACA 0010, NACA 64A010, and parabolic arc, will be examined in detail to determine the effects of airfoil shape. Thickness effects will be examined through comparison of results for the NACA 0010 and NACA 0012 (12% thickness/chord) airfoils. Calculations will also be performed varying angle of attack and airfoil camber to investigate their effects on the shock location and transonic unsteady airloads. The study will be directed at establishing guidelines, where appropriate, for the effects of these parameters upon transonic flows.

Figure 67.

OSCILLATING PRESSURE MEASUREMENTS ON A 2-D SUPERCRITICAL WING IN THE 1/3 METER CRYOGENIC TUNNEL

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Unsteady Aerodynamics Branch
Extension 2661
and
William B. Igoe
NTF Aerodynamics Branch
Extension 2601

RTOP 505-33-43

Research Objective - High quality unsteady pressure measurements obtained from oscillating airfoils and wings are needed to calibrate transonic computational predictions. The influence of viscosity upon these unsteady airloads needs to be determined since flight Reynolds numbers range up to 100 million whereas past wind tunnel experiments have only reached Reynolds numbers of 10 million. The National Transonic Facility, operating at cryogenic temperatures, will allow testing at flight Reynolds numbers and the LANN wing model will be the first unsteady pressure test in this facility. Prior to testing the LANN wing, valuable two-dimensional unsteady pressure data at Reynolds numbers up to 40 million and operational experience at cryogenic temperatures will be obtained in a test in the 1/3 meter pilot cryogenic wind tunnel.

Approach - There are four objectives to this research task. They are to (1) measure oscillating pressures at high Reynolds numbers for comparison with developing 2-D unsteady computer codes, (2) measure the extent of change in oscillating pressures on a supercritical airfoil due to change in Reynolds number, (3) compare developed oscillating pressures at low Reynolds number using a suitable boundary layer transition step with oscillating pressures on a base airfoil at high Reynolds numbers and (4) to assess the instrumentation installation and data reduction techniques to be used in the LANN wing test at the NTF.

Future Plans - A fourteen percent supercritical airfoil (NASA TM 81912) model designed to measure static pressures in the 1/3 m Cryo tunnel will be modified to measure unsteady pressures. The model (6 in chord, 8 in span) is made of 15-5 steel. A complete hydraulic pump unit capable of oscillating the model at frequencies from 4 to 40 hertz is available. The wind tunnel test section will be modified to accomodate the oscillating airfoil unit and the test is planned for the summer of 1984.

Figure 68(a).

NASA
L-82-10,404

TWO-DIMENSIONAL CRYOGENIC OSCILLATING PRESSURE MEASUREMENTS

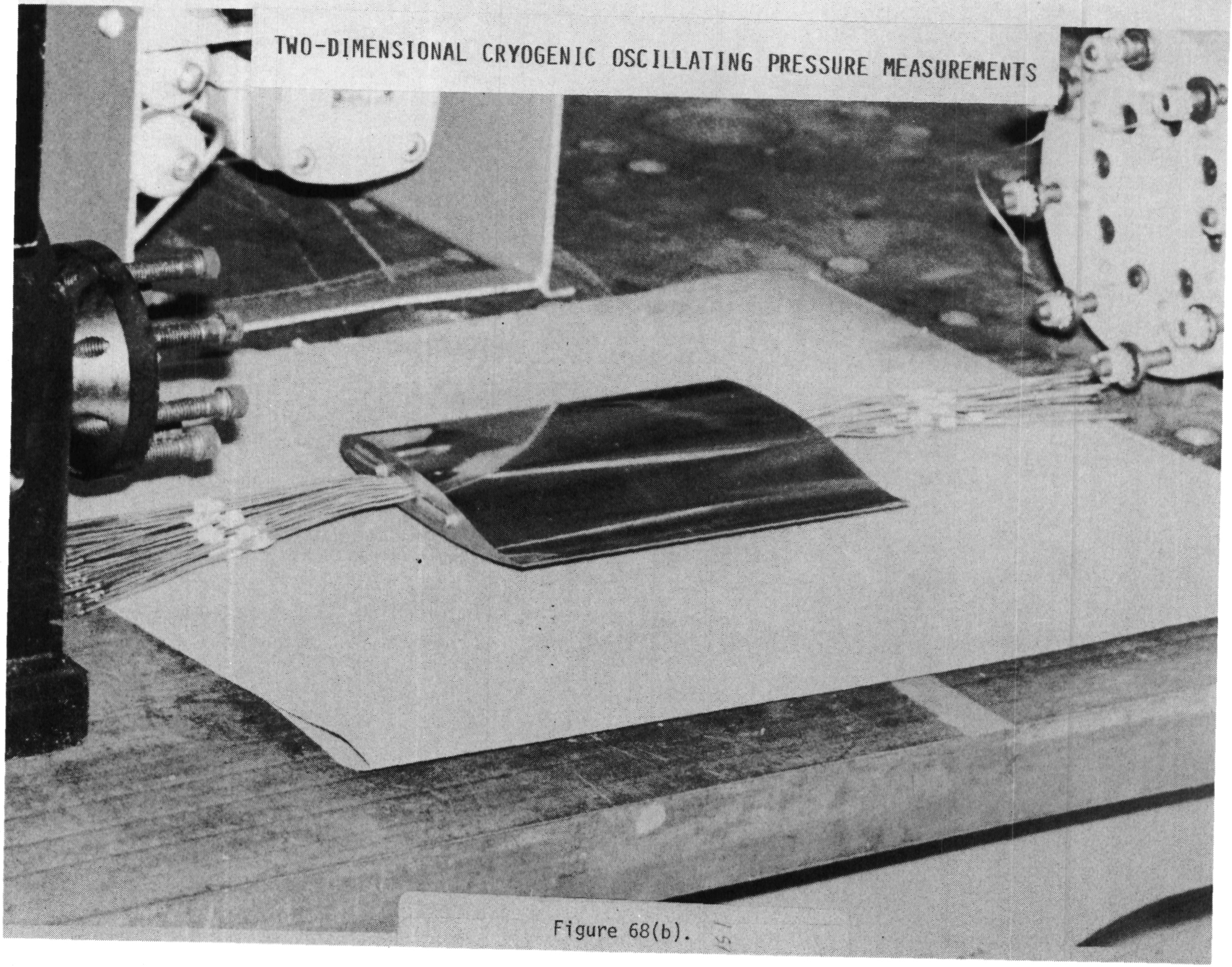

Figure 68(b).

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PITCHING AND PLUNGING SUSPENSION SYSTEM
FOR 2-D TRANSONIC FLUTTER TESTING

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Configuration Aeroelasticity Branch
Extension 2661

RTOP 505-33-43

Research Objective The objective of this effort is to build an apparatus to enable systematic study of transonic flutter in Langley's 6" x 28" 2-D transonic blowdown tunnel.

Approach - Simple analogs of physical systems are frequently used in engineering to simulate complex processes with simpler ones. Two-dimensional airfoil models have been used for static tests since the beginning of aeronautics. However, mechanisms to simulate wing flutter with two-dimensional airfoil sections have been conspicuously absent. This is due to the difficulty of implementing the linear and rotational springs required to simulate the plunging and pitching motions while maintaining realistically lightweight moving masses. The approach to be used in this effort uses a novel compound spring system to keep spring deflections within reasonable limits while generating the large forces needed to counteract the transonic airloads. This will allow the effect of steady angle of attack upon the flutter boundary to be studied. The spring system will also allow the pitch and plunge frequencies to be varied over a reasonably wide range. In addition, the pivot location for the pitching motion will be adjustable so that motions similar to those of swept-back wingtips may be simulated.

Future Plans - The apparatus will be built during the coming year. Initial checkout will include measurement of unsteady pressures on two airfoils, an MBB A-3 section,and an uncambered MBB A-3 section. Following checkout, the sections will be replaced with lighter weight airfoils and flutter tests conducted for a range of frequencies and steady angles of attack.

Figure 69.

DECOUPLER PYLON PROGRAM

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Configuration Aeroelasticity Branch
Extension 2661

RTOP's 505-33-43 and 533-02-73

Research Objective - To demonstrate passive suppression of wing/store flutter on a modern lightweight fighter airplane.

Approach - The Decoupler Pylon Program consists of analyses, wind tunnel tests, and flight tests of a NASA patented pylon. The decoupler pylon dynamically isolates the wing from external store pitch inertia effects by means of soft-spring and damper components. An alignment system can be incorporated to minimize static pitch deflections of the store due to maneuvers and aerodynamic loads. Analyses and wind-tunnel tests of YF-17 and F-16 flutter models with stores have shown increases in flutter dynamic pressure in excess of 100-percent over the same stores mounted on standard pylons.

The flight test program will demonstrate flutter suppression on the F-16 with the same store configuration tested in the wind tunnel. The decoupler pylon goal is to demonstrate a 70-percent increase in flutter dynamic pressure over a production pylon. The flight tests will also bring into focus the effects of turbulence, flight maneuvers, store ejection and flight control system interactions.

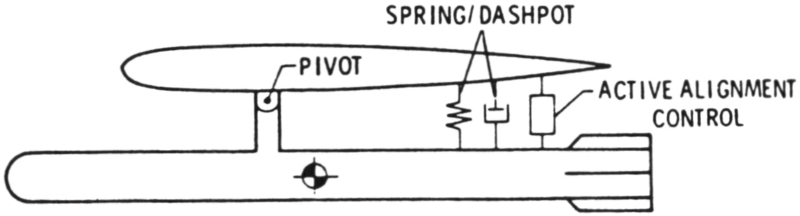
Status/Plans - Fabrication of the decoupler pylons has been completed. The pylons have been instrumented, and all planned ground tests of the pylons have been successfully completed. A potential problem with stiction/starting friction in the pylon linkages was identified during the ground tests, but analysis of expected flight loads indicated that a sufficiently large dither load will be present to insure that the pylon linkage will be free during the flight tests.

The pylons have been shipped to NASA Dryden. The flight test program is scheduled to begin in the fall of 1983. The flight tests may slip because the USAF F-16 airplane (A2 airframe) that will be used is also being used for some other flight tests programs which the USAF considers of higher priority than the decoupler pylon.

Figure 70(a).

DECOUPLER PYLON — A PASSIVE FLUTTER SUPPRESSOR

JOINT LaRC AND DFRF PROGRAM



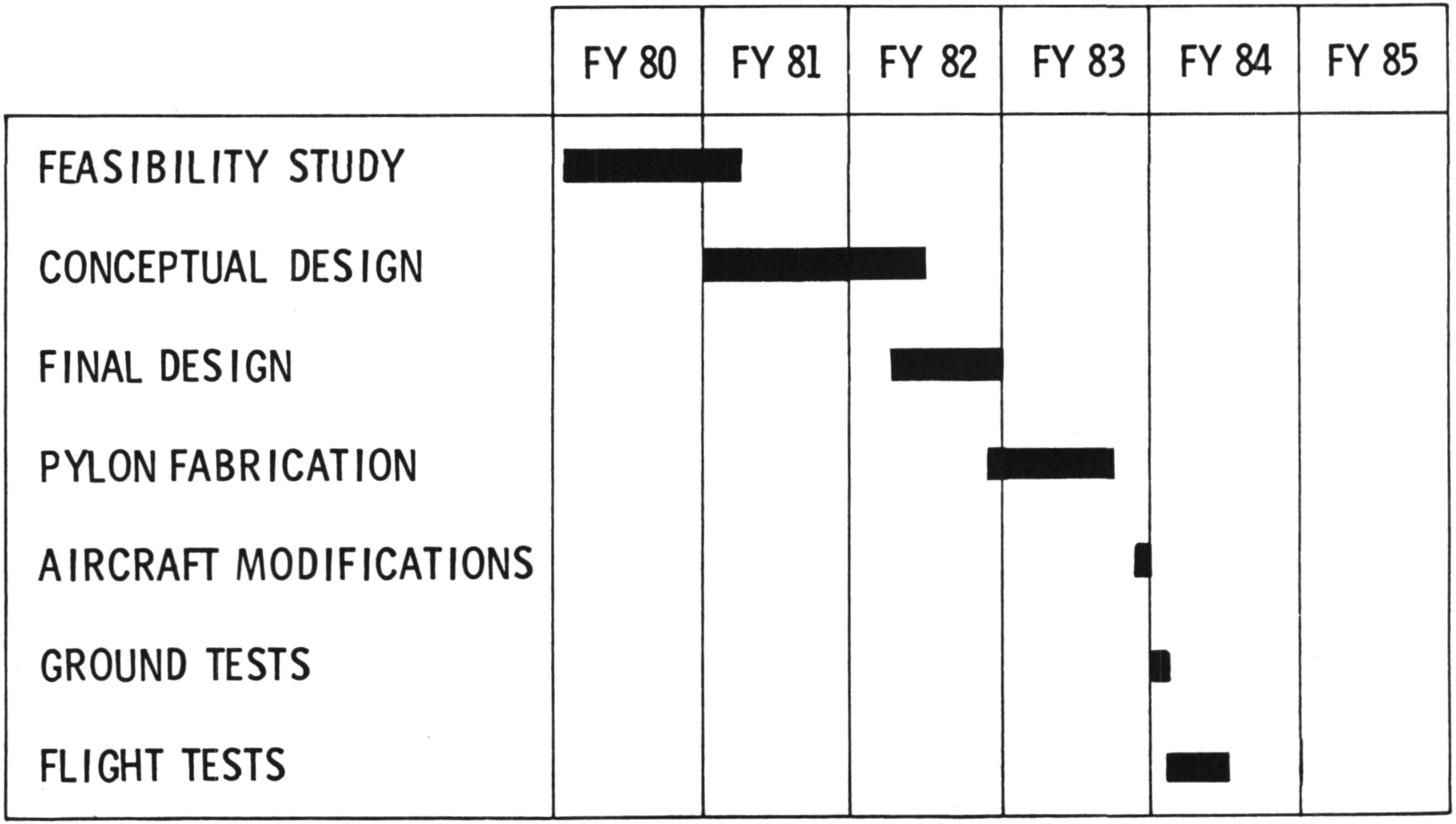


Figure 70(b).

MODIFICATIONS TO UPGRADE THE LANGLEY TRANSONIC DYNAMICS TUNNEL (DENSITY INCREASE)

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Extension 2661

Background - The TDT is designed for and dedicated to studies and tests in the field of aeroelasticity and has special features which make it a national resource for flutter and buffet tests. The facility is used to verify the flutter and aeroelastic characteristics of most U.S. high-speed aircraft designs; for rotorcraft and active controls research; for flutter, buffet, and ground-wind loads tests of the Space Shuttle and other launch vehicles; and for confirmation of unsteady transonic flow theory. The increased density capability is needed chiefly for development testing involving the flutter clearance and validation of the flutter characteristics of high-speed aircraft and space vehicles such as the Shuttle. Models of these aircraft must be dynamically and aeroelastically scaled if the tests are to be valid. In addition to simulating the external shape, the stiffness, and stiffness distribution, these models must also simulate the mass density ratio which is the ratio of the distributed mass of the vehicle to the mass of the flight medium surrounding it. As airplanes become lighter (more structurally efficient), as with the use of composite major structures, or as they incorporate the use of active controls (which means the models have to employ relatively heavy active control hydraulic systems internally), it becomes increasingly difficult to fabricate models which are light enough to match full-scale mass-density ratios with current TDT density capability.

Approach - This FY 83 CofF project will provide for increasing the maximum test density by 50% in the Mach number range from 0.6 to 1.2. The increased density capability will be provided by rewinding the existing fan motor to increase the power rating from 20,000 hp to 30,000 hp. Additional tunnel cooling capacity will be provided to support the increased tunnel power limit. Other major modifications include changes to the electrical power distribution system and installation of a new speed control system.

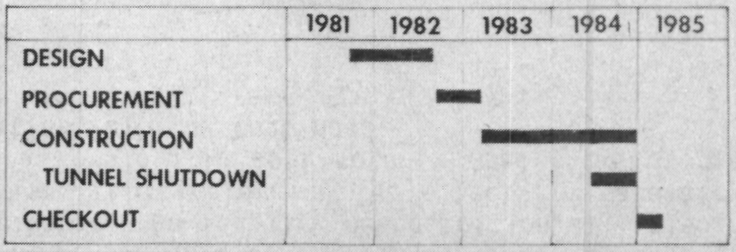
Status/Plans - The design for the modifications, which was developed under contract by DSMA Engineering Corporation, provides for dividing the work into a series of independent work packages to be performed by separate contractors. Contracts have been awarded for five of these work packages. These contracts encompass the major portions of the work to be done, namely, increasing the fan horsepower, installing new cooling system, and modifying electrical distribution system. Contracts for the other two work packages will be awarded later, as originally planned. Installation of the modifications are expected to take about six months, beginning in mid 1984, followed by a three months checkout period. Some off-site work and on-site work that does not interfere with tunnel operations (for example, addition of cell to cooling tower) has already begun. The TDT is expected to be fully operational with the increased density capability in April 1985.

Figure 71(a).

NASA
L-82-8,554

TDT DENSITY INCREASE

SCHEDULE



INCREASED PERFORMANCE

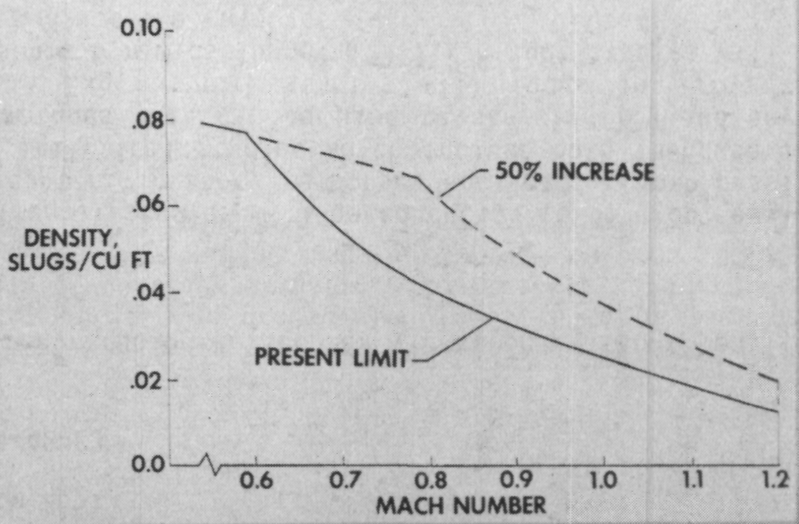


Figure 71(b).

ROTORCRAFT VIBRATION REDUCTION

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RTOP 505-42-23

Research Objective - To develop and validate methods for reducing helicopter vibrations without penalizing helicopter performance.

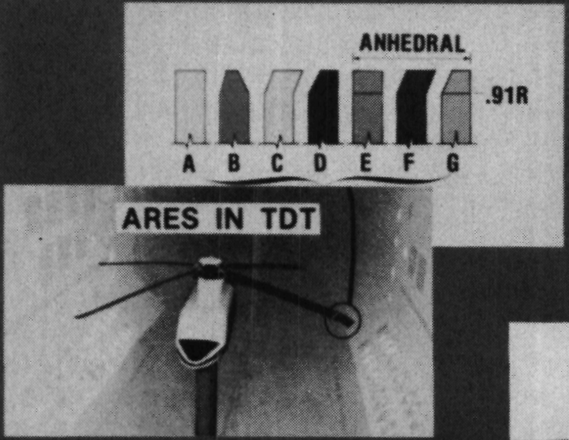
Approach - A balanced program of analytical and experimental studies will be conducted to develop, evaluate, and validate promising methods for reducing helicopter vibratory responses and loads. Both passive and active control approaches will be addressed. The analytical studies which include both in-house and out-of-house studies with the focus being to study methods that can be used to structurally and aerodynamically tailor the blades to reduce vibrations. Experimental studies will focus on using the Advanced Rotor Experimental System (ARES) in the Transonic Dynamics Tunnel (TDT). Flight studies will be conducted when appropriate, but will be the exception and not the rule.

Future Plan - The final closed-loop flight tests of the Higher Harmonic Control (HHC) vibration suppression system implemented on an OH-6A helicopter will be completed. An industry demonstration will also be held to maximize technology transfer. Further tests in the TDT to determine the effects of parametric changes in rotor blade tip geometry will be conducted on a torsionally soft rotor. Analytical studies for structurally optimizing rotor blades to minimize vibrations will be continued.

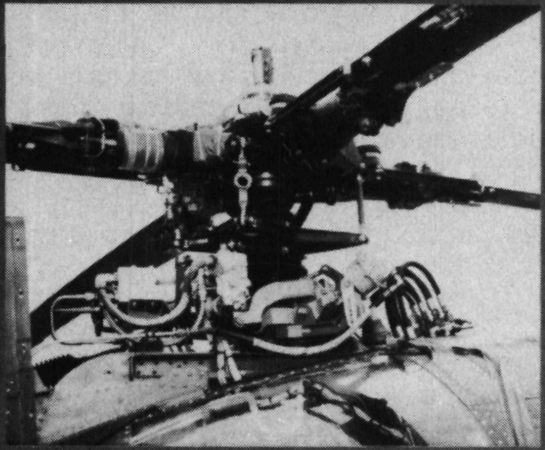
Figure 72(a).

NASA
L-83-7,907

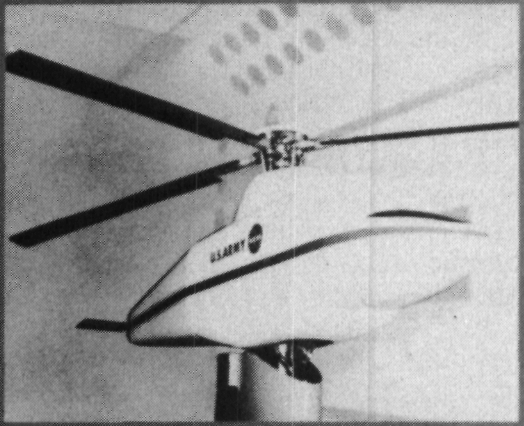
VIBRATION REDUCTION



TIP SHAPE STUDIES



HIGHER HARMONIC CONTROL



AEROELASTIC TAILORING

ACTIVE AND PASSIVE REDUCTION OF VIBRATIONS AND DYNAMIC LOADS

Figure 72(b).

A NATIONAL CAPABILITY TO ANALYZE VIBRATION AS PART OF HELICOPTER STRUCTURAL DESIGN

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RTOP 532-06-13

Research Objective - Helicopters are prone to vibrations which can seriously degrade both service life and ride quality. With only a few exceptions vibrations problems have not been identified and attacked until the flight test and operational stages. There is now a recognized need to account for vibrations during the analytical phases of design. The advent of modern methods of computer analysis has provided the opportunity to achieve such a capability. The objective is to emplace in the United States a superior capability for design analysis of helicopter vibrations.

Approach/Status/Plans - As a culmination of considerable planning and coordination work by NASA and the Helicopter Industry, requests for proposals (RFP's) have been issued for contracts under which Industry teams will carry out analysis, measurement, correlation, and mutual critique procedures designed to develop confidence in finite element analysis methods to predict vibrations of helicopter airframes. The approach follows the recently completed project at Boeing Vertol where the analysis subject was the CH-47D airframe. The airframes to be treated are: Metal Airframes: (1) Hughes AH-64, and (2) Sikorsky UH-60; Composites Airframes: (3) Bell ACAP, (4) Sikorsky ACAP, (5) Boeing Vertol Model 360, and (6) Hughes 500D Composite Version. The current schedule calls for these exercises to be completed by mid FY 1986. Possibilities of utilization of scheduled Army developmental vibrations tests are being investigated, and this could result in completion by the end of FY 1985. The RFP's also contain provisions for industrial teams during FY 1984 to apply methods for coupled rotor-airframe vibrations analysis. Participation is expected from Bell, Hughes, and Sikorsky and from a NASA/Army inhouse team as well. Various methods available to the teams will all be applied to one helicopter, the Bell AH-1G. The results will be correlated with existing flight vibrations data. The manufacturer Bell has the special responsibility to describe the vehicle, provide a previously developed finite element model of the airframe, and explain the background of existing ground and flight vibrations data. During FY 1985 Bell will improve the airframe finite element model based on additional ground vibrations measurements and based on the correlations with flight vibrations data presented by the four teams. A survey of universities has been set up to assess the state-of-the-art in teaching the engineering of aeronautical structures. First mailing to Universities will take place shortly. It is planned to publish the results of the survey.

Figure 73(a).

ROTORCRAFT VIBRATIONS PLANS

O CARRY OUT FY-84 ELEMENTS OF BASIC MODELING EXERCISES

- FINITE ELEMENT MODEL: HUGHES AH-64 AIRFRAME
- FINITE ELEMENT MODEL: SIKORSKY UH-60 AIRFRAME
- REQUIREMENTS: FY-85 VIBRATION MEASUREMENTS: AH-64 AIRFRAME
- REQUIREMENTS: FY-85 VIBRATION MEASUREMENTS: UH-60 AIRFRAME
- VIBRATION MEASUREMENTS: BOEING VERTOL MODEL 360 AIRFRAME
- MODELING PLAN: FY-85 FINITE ELEMENT MODEL: MODEL 360 AIRFRAME

O CARRY OUT COUPLED ROTOR-AIRFRAME VIBRATIONS EXERCISES ON BELL AH-1G HELICOPTER (BELL, HUGHES, NASA, AND SIKORSKY)

O DEFINE ELEMENTS OF FY 86 - FY 88 ADVANCED TECHNOLOGY PROGRAM

- COUPLED ROTOR-AIRFRAME VIBRATIONS ANALYSIS
- OPTIMIZATION ACCOUNTING FOR AIRFRAME VIBRATIONS
- AIRFRAME DAMPING MODEL
- FATIGUE LOADS MODEL
- SCIENTIFIC MODEL IMPROVEMENT

Figure 73(b).